Lower Thames Crossing

6.3 Environmental Statement Appendices
Appendix 10.11 – Remediation Options Appraisal and Outline Remediation Strategy (Clean version)

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Lower Thames Crossing

6.3 Environmental Statement Appendices Appendix 10.11 – Remediation Options Appraisal and Outline Remediation Strategy (Clean version)

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1 Executive summary

1.1.1 This Remediation Options Appraisal and Outline Remediation Strategy report identifies potential remediation options associated with possible land quality and contamination issues around the proposed A122 Lower Thames Crossing (the Project) route. The purpose of this report is to demonstrate that available remediation techniques exist to treat the pollutant linkages identified and potentially unidentified contamination present, if required. The report will also detail remediation objectives, how the remediation will be implemented and then verified. Furthermore, refinement of the conceptual site model (CSM) will be undertaken by Contractors on behalf of National Highways, including (if required) a detailed quantitative risk assessment (DQRA) at detailed design stages which will determine whether remediation is necessary and, if so, which of the identified remediation techniques should be selected.

Summary

Remediation objectives

The investigation reports to date have identified plausible pollution linkages associated with discrete soil contamination (heavy metals, polycyclic aromatic hydrocarbons (PAH) and asbestos), an asbestos irrigation pipe and one active petrol filling station within the Project. It is considered that any unacceptable risks to human health and controlled waters posed by these pollutant linkages, and low risk sites, can be avoided or mitigated by measures outlined in the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2) (specifically GS001, GS006, GS0016, GS017, GS018, GS0026, GS027 and GS028) and the remediation methodologies within this report.

In addition, the investigations have identified data gaps and uncertainties associated with the medium and high-risk sites which require further assessment and possible remediation as detailed in Appendix 10.9 (Application Document 6.3).

The objective of this report is to provide and detail options that will mitigate the risks associated with unexpected contamination or where potential contaminative sources identified have not been fully investigated, at medium to high-risk sites.

The remediation objectives which will be considered in selecting techniques to ensure remediation are:

- undertaken in line with the principles outlined in Land Contamination Risk Management (LCRM) (Environment Agency, 2021), including sustainability.
- meets the requirements of the Development Consent Order (DCO).
- does not adversely impact timescales for construction of the Project.
- meets other local constraints identified such as noise, odour, and duration.
- can be achieved within the space and access constraints for each area of remediation.
- meets the requirements of a cost benefit test.

Residual contamination risks

- Following the GIs and subsequent assessment of the data which is discussed in the Generic Quantitative Risk Assessment (GQRA) reports (Annex A–D) (Application Document 6.3, Appendix 10.9), the number of potential contaminant sources and the risk they present were refined on the basis that some pollutant linkages could be dealt with by standard construction practices as presented and committed to in the CoCP and REAC.

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- Where a low-risk rating has been determined following the GQRA, it is considered that for these sources, either no further action was required or that standard construction processes and environmental procedures as detailed in the REAC would be sufficient to manage any risks present.
- The refined assessment approach identified 16 credible contaminant sources / sites with a medium or high-risk rating, as needing further assessment, remediation, and specific design. Sites subjected to ground investigations were found to be impacted by discrete heavy metal, PAH, and asbestos soil contamination. Elevated ground gases and vapours were recorded within the Goshems Farm Landfill.
- Discrete heavy metal, PAH and asbestos soil contamination was identified in localised pockets of made ground or natural soils, where no credible contaminant sources were recorded. These contaminants are considered to be reflective of the made ground, windborne inclusions from unknown sources or cross-contamination.
- Elevated ground gases and vapours were also detected in Alluvium along the proposed Project route.
- The GQRA report concluded that the contamination identified by the ground investigations posed a risk to construction workers and operational staff.
- Groundwater exceedances of the controlled waters GAC were recorded. However, these were considered to be reflective of natural background conditions or up hydraulic gradient contamination sources outside the Order Limits. Nevertheless, this report and the Project look to prevent input of pollutants into the water environment and achieve betterment in groundwater quality, through the reduction of infiltration following the construction of road surfaces, surface water drainage control, and compaction of beneath the site.
- The identified residual contamination risks, are addressed by this report and under works to be undertaken by the Contractor on behalf of National Highways as per the requirements of REAC GS001.

Remediation options appraisal

A shortlisted feasible remediation options appraisal has identified a range of in-situ and ex-situ biological, chemical, thermal, physical, and civil engineering-based methods, to mitigate the potential contaminants of concern, data gaps and uncertainties identified at medium and high-risk sites.

Given the nature of discrete contaminants identified by the ground investigations to date, the current land uses and the proposed highway scheme, it was not envisaged that complex in-situ and ex-situ biological, chemical, and thermal remediation methods would be required. Furthermore, as no groundwater contamination to date has been linked to the credible sources within the Application Site, remediation methods specific to groundwater contamination are not considered necessary. Therefore, the following physical and civil engineering-based remediation methods, specific to soil contamination, were considered to be more practical and shortlisted for detailed evaluation:

- Containment (e.g., capping layers or cover systems).
- Excavation and disposal.
- Solidification and stabilisation.
- It was considered that the risks associated with ground gases and vapours would be managed by engineering measures through the design of structures implemented by the Contractor under REAC GS0018.
- Following the detailed evaluation, it was considered that a combination of containment, excavation and disposal were the preferred remediation options, given their proven track

Summary

record, duration, and availability. It was further considered that the reuse of soils beneath cover systems would reduce disposal costs and the environmental impact of landfilling.

Remediation and reuse criteria

- Following the completion of supplementary ground investigations and detailed design, the Contractor should derive site specific assessment criteria for the Project that are protective of both human health and controlled waters.

Preparatory works activities to support remedial actions

Prior to the commencement of remediation works in relation to the medium and high level risk sources as identified through the GQRA process, the following activities would be undertaken (as appropriate):

- Supplementary ground investigations (REACs GS001 and GS018)).
- Detailed remediation design (REAC GS027).
- Material management plan and/or Waste Recovery Plan in accordance with the Definition of Waste Code of Practice or a Bespoke Environmental Permit, respectively (REAC MW007 and GS006)).
- Remediation method statements, including asbestos management plan and monitoring action plan.
- The monitoring action plan should detail which monitoring wells are to be retained and protected for long-term monitoring. The plan should also identify redundant wells which require decommissioning in line with EA guidance, to prevent them from becoming preferential pathways for mobile contaminants. Foundation works risk assessment (REAC GS027).
- Obtain land access.
- Obtain licenses and permits.

Outline remediation strategy

Key tasks relating to the remediation of plausible pollutant linkages are likely to include the following, with further details provided in Section 7:

- Decommissioning of redundant monitoring wells.
- Decommissioning and removal of fuel storage tanks.
- Excavation and removal of asbestos containing pipe.
- Earthworks.
- Management of unexpected contamination.
- Groundwater management.
- Ground gas and vapour protection measures.
- New landscaping areas.

Verification

The following verification processes will need to be undertaken to demonstrate the risks identified by the ground investigation will be reduced to meet the agreed remediation criteria objectives:

- A general watching brief should be undertaken during earthworks and construction works for visual or olfactory evidence of contamination.
- A discovery strategy should be commissioned and followed should any unexpected ground and groundwater contamination be encountered during the watching brief (as per Requirement 6 of the DCO). Upon discovery of unexpected contamination, works

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should stop, and the appointed geo-environmental consultant should be contacted promptly to investigate and identify an appropriate remediation method to manage the contamination (if required).

- Validation sampling and monitoring of soils, airborne asbestos fibres, groundwater, surface waters, ground gases and vapours.
- Remediation progress reporting.
- Verification reporting.
- Post-Construction Management Plan.

2 Introduction

2.1 Background information

2.1.1 This report identifies potential remediation options associated with possible land quality and contamination issues around the proposed A122 Lower Thames Crossing (the Project) road. The Project would provide a connection between the A2 and M2 in Kent, east of Gravesend, crossing under the River Thames through two bored tunnels, before joining the M25 south of junction 29.

2.1.2 The A122 road would be approximately 23km long, 4.25km of which would be in tunnel. On the south side of the River Thames, the Project route would link the tunnel to the A2 and M2. On the north side, it would link to the A13 and junction 29 of the M25. The tunnel portals would be located to the east of the village of Chalk on the south of the River Thames and to the west of East Tilbury on the north side.

2.1.3 The purpose of this Remediation Options Appraisal and Outline Remediation Strategy is to demonstrate that available remediation techniques exist to treat the pollutant linkages identified and potentially unidentified contamination present, if required. Further refinement of the Conceptual Site Model (CSM) will be undertaken by Contractors including (if required) detailed quantitative risk assessment (DQRA) at detailed design stages which will determine whether remediation is necessary and, if so, which of the identified remediation techniques should be selected.

2.1.4 This report builds on the findings of the Preliminary Risk Assessment (PRA) Report (Application Document 6.3, Appendix 10.6) and the Generic Quantitative Risk Assessment (GQRA) reports (Annex A–D) (Application Document 6.3, Appendix 10.9). The PRA report sets out the potential pollutant linkages along the route and these are further examined and refined in the GQRA reports, to provide a list of relevant pollutant linkages across the Project which need further consideration. Using this information, this Remediation Options Appraisal and Outline Remediation Strategy identifies potentially suitable remediation technologies to reduce the risk from the relevant pollutant linkages.

2.1.5 For the purpose of this report, the Project route has been divided into four sections as Package A to Package D.

2.1.6 The location and extent of the four packages are shown on Figure HE540039-CJV-GEN-GEN-MAP-GEO-00222 in Annex A.

2.2 Sources of information

2.2.1 The following sources of information have been used to produce this report:

a. Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

b. Appendix 10.9: Generic Quantitative Risk Assessment (GQRA) reports for the Phase 2 Investigation (Annex A–D) (Application Document 6.3).

2.3 Project stakeholders and responsibilities

2.3.1 The project stakeholders and their responsibilities are summarised in Table 2.1.

Table 2.1 Project Stakeholders

Stakeholder	Role/ Interest
National Highways	Responsible for developing, promoting, and operating the Project. Provide necessary assessments, site data and outline remediation strategy to allow the contractor to produce a detailed design and specification for remedial works where required.
Contractor	The Contractor will be responsible for the design and execution of the remedial works on behalf of National Highways.
Environment Agency	Statutory consultee with an interest in the protection of controlled water receptors and reuse/ disposal of materials.
Local Planning Authority	Local Authority statutory consultee with an interest in the management of potential risks to human health from contaminated land.
Landowners	Current owners of the land being developed to facilitate the project.
Local communities/ businesses	Surrounding land users and businesses.

2.4 Method

Introduction

2.4.1 This Remediation Options Appraisal and Outline Remediation Strategy Report has been developed with reference to the guiding principles set out in Land Contamination: Risk Management guidance (LCRM) (Environment Agency, 2021), with the objectives of:

a. outlining general remediation objectives with which any future remediation must comply.

b. identifying potentially suitable remediation techniques for contaminant sources identified along the Project's proposed road.

c. identifying the next steps required to progress the remediation options review process.

   i. clearly set out how the selected remediation option(s) will mitigate the risks from relevant contaminant linkages identified in the CSM.

   ii. meet the remediation objectives and criteria set in the options appraisal.

   iii. meet any regulatory requirements.

iv. be compatible with other areas of works.

v. state how it will protect receptors.

vi. provide a sustainable approach.

vii. be practicable, achievable, effective, durable, and verifiable.

Land contamination risk management process

2.4.2 The land contamination risk assessment presented herein is based upon the process laid out in the LCRM guidance (Environment Agency, 2021). In brief, the assessment is a tiered process with increased site-specific understanding required at each level:

a. **Stage 1: Risk assessment -The three tiers are:**

i. Preliminary risk assessment

ii. Generic quantitative risk assessment

iii. Detailed quantitative risk assessment

b. **Stage 2: Options appraisal - The three tiers are:**

i. Identify feasible remediation options

ii. Detailed evaluation of options

iii. Selection of final remediation options

c. **Stage 3: Remediation - The three tiers are:**

i. Develop a remediation strategy

ii. Remediation and verification

iii. Long-term monitoring and maintenance, if required

2.4.3 The remediation options appraisal for the Project falls within Stage 2 of the LCRM guidance (Environment Agency, 2021) and the development of a remediation strategy is the initial step of Stage 3 of this tiered approach. The phases, and how they relate to the LCRM, are presented in Plate 2.1.

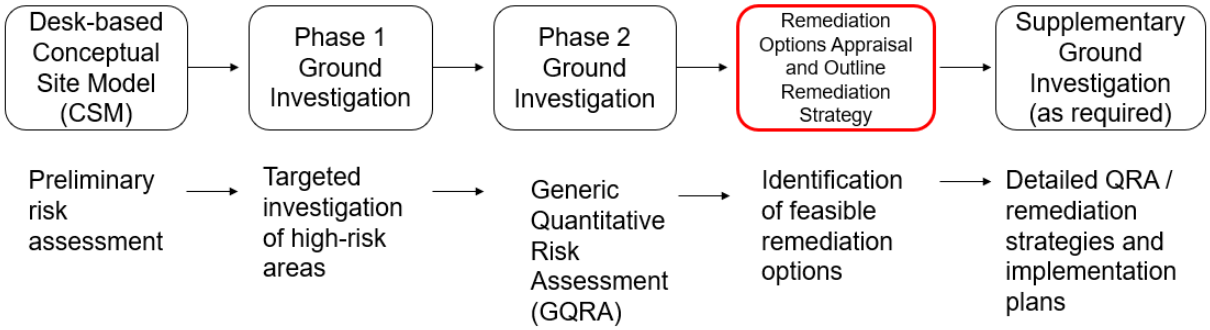
2.4.4 The first stage of the risk assessment is the production of a CSM which establishes whether there are any potentially unacceptable risks (potential pollutant linkages) and supports the design of the intrusive ground investigations. The subsequent Generic Quantitative Risk Assessment (GQRA) then utilises the findings of the ground investigations to assess if there are unacceptable or acceptable risks associated with the identified potential pollutant linkages by comparing the contaminant concentrations against appropriate general acceptance criteria (GAC). A precautionary approach has been adopted for the purposes of the GQRAs whereby if the assessment of the

results of the ground investigation reveals unacceptable risk or uncertainty, then the assumption is that the pollutant linkage remains relevant and further action may be required.

2.4.5 The GQRA for the Phase 2 Investigation is presented in Application Document 6.3, Appendix 10.9 and is based upon the data collected as part of the Phase 2 ground investigation. Phase 2 was intended to build upon the investigation carried out in Phase 1 and refine the findings through the production of a GQRA. The main objective of the GQRA is to identify where risks arising from potential contamination exist so that they can be included within the mitigation measures (i.e., remediation) relating to land contamination for the Project.

2.4.6 Once the DQRA is completed as part of detailed design, the list of feasible remediation options will be further refined /reduced as it becomes clearer what contaminants truly require remediation / risk management.

Plate 2.1 Summary of the main phases of work completed/underway and their relation to the Land Contamination Risk Management process



2.5 Remediation objectives

2.5.1 The refined CSM across the Project has identified one high risk site,15 medium risk sites with the remaining credible sources being rated as low risk. It is considered that any unacceptable risks to human health and controlled waters posed by these pollutant linkages, and low risk sites, can be avoided or mitigated by standard protocols outlined in the REAC (specifically within REACs GS001, GS006, GS0016, GS017, GS018, GS0026, GS027 and GS028) and the remediation methodologies within this report.

2.5.2 In addition, the investigations have identified data gaps and uncertainties associated with the medium and high-risk sites which require further assessment and possible remediation.

2.5.3 Therefore, the objective of this report is to identify techniques that could be implemented by the Contractors for the remediation of contamination (REAC Ref. GS027). These objectives are likely to be fulfilled by controlling or breaking the identified pollutant linkages. This would principally be removal of the source of contamination or by breaking the pathway between the source

and the receptor, given the practicalities and linear nature of the infrastructure development proposed.

2.5.4 Remediation objectives require that selected techniques ensure the remediation:

a. is undertaken in line with the principles outlined in LCRM (Environment Agency, 2021), including sustainability.

b. meets the requirements of the Development Consent Order (DCO).

c. does not adversely impact timescales for construction of the Project.

d. meets other local constraints identified such as noise, odour, and duration.

e. can be achieved within the space and access constraints for each area of remediation.

f. meets the requirements of a cost benefit test.

2.5.5 The general remediation objectives provide guiding technical, operational, and commercial principles for the remediation.

2.5.6 This Remediation Options Appraisal and Outline Remediation Strategy report demonstrates that there are practical remediation techniques available that would meet the objectives. The preliminary choice of remediation techniques and conclusions drawn are supported by the assessments undertaken to date, including the PRA Report, and GQRA Reports.

2.5.7 This Report does not aim to finally identify which remediation techniques are required but provides an indicative approach that could be adopted by the Contractor for the relevant pollutant linkages that have been identified.

2.5.8 The Phase 2 ground investigation has targeted the Order Limits and areas where proposed intrusive works are planned as part of the construction phase. Where exploratory locations have recorded an exceedance of the applicable Generic Assessment Criteria (GAC) and fall within a credible source of contamination identified within the CSM, it suggests that the exceedances may be reflective of impacts from that particular source and the presence of a complete pollutant linkage. Where the GAC are exceeded, the results would be evaluated to determine whether the level of risk is acceptable or whether further assessment would be required at the detailed design stage of the Project. After appropriate assessment and where unacceptable risks are identified, the Contractor would develop proposals for site-specific remediation strategies and implementation plans. The commitment for these requirements is made in the REAC (GS001 and if required, GS027).

2.5.9 Once detailed design is complete, site-specific remediation strategies would be prepared by the Contractor(s) and agreed with the regulators prior to remediation taking place as committed to with the REAC (Ref GS027).

3 Conceptual site model, data gaps and uncertainties

3.1 Conceptual site model

Credible contaminant sources

3.1.1 The Preliminary Risk Assessment (PRA) Report (Application Document 6.3, Appendix 10.6) identified over 200 features within the study area which are a potential contaminant source. Features were included when they could form a credible pollutant linkage that may affect the Project.

3.1.2 Following the ground investigations and subsequent assessment of the data which is discussed in the GQRA reports (Application Document 6.3, Appendix 10.7 Annex A-D), the number of potential contaminant sources and the risk they present has been refined. The refinement of the credible contaminant sources included a desk-based assessment of the Order Limits and proposed works to assess if those sources could be discounted or addressed by construction practices as presented and committed to in the Code of Construction Practice (CoCP) and the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2) The sources were given a revised risk rating on this basis.

3.1.3 Where it has been determined following the GQRA, it is considered that these could be discounted or would be managed under the commitments made in the CoCP and REAC, including the specific requirements of GS028, GS006 and GS018, these have been attributed with a low-risk rating.

3.1.4 Following the refinement, credible contaminants sources which have been given a medium or high-risk rating as further assessment and possible remedial works / specific design may be required. Table 3.1 details the medium and high-risk sites from across the Project and their location are shown on Figure HE540039-CJV-GEN-GEN-MAP-GEO-00222 in Annex A. These have been taken forward and for which feasible remediation options are established (as set out in section 4).

Table 3.1 Summary of medium and high-risk credible contaminant sources (source GQRA reports Application Document 6.3, Appendix 10.9 Annex A-D)

Package	Name (HLU)	Discussion from GQRA reports	Refined qualitative risk rating
A	Esso A2 Westbound Petrol Filling Station (HLU0215)	The site is an operational petrol filling station (PFS), with known (minor) hydrocarbon impacts to soil. The site was redeveloped in 2010 and environmental condition reports are available. The existing PFS is located on the proposed route alignment and proposed utility works. The PFS would	Medium

Package	Name (HLU)	Discussion from GQRA reports	Refined qualitative risk rating
		be removed as part of the works. The potential source requires further assessment and possible remedial works.	
B	Nursery (HLU0330)	The plant nursery is located within the Order Limits in an area of cutting. A proposed bridge is in the northern portion of the potential source. Intrusive utilities are also proposed running across the potential source. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage. No intrusive ground investigation works have been undertaken at the potential source to date. Consequently, further assessment and possible remedial works are required.	Medium
C	Southern Valley Golf Course (HLU0324)	The site is located within the Order Limits in the southern tunnel approach. The proposed works would involve significant cutting works. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Results of the ground investigation have indicated the presence of potential lead, PAH, and asbestos soil contamination in the made ground and natural ground. Asbestos fibres were detected in BH02003, WS02002, WS02005 and WS02007. Therefore, there is a possible plausible pollutant linkage. The potential source requires further assessment and possible remedial works / specific design.	Medium
D	Tilbury Ash Disposal Site - Area A2 (HLU0531) and A3 (HLU0530) Area B (HLU529), Area C (HLU0528) and	The potential sources are located in the order limits at the north portal and in an area proposed for utility works. The potential source is likely to be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage.	Medium

Package	Name (HLU)	Discussion from GQRA reports	Refined qualitative risk rating
	Area C2 (HLU0527)	Impacts to surface waters adjacent to the site have been attributed to the landfill. Although no unacceptable ground contamination was identified by the ground investigation, the potential for unidentified contamination still exists given the site's landfilling history. Therefore, further assessment and possible remedial works may be required.	
E	Tilbury Ash Disposal Site - Shed Marsh Landfill (HLU0534)	The potential source is located in the Order Limits at the north portal and intrusive utility works are proposed in the northern portion of the potential source. The potential source is likely to be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage. Impacts to surface waters adjacent to the site have been attributed to the landfill. Although no unacceptable ground contamination was identified by the ground investigation, the potential for unidentified contamination still exists given the site's landfilling history. Therefore, further assessment and possible remedial works may be required.	Medium
F	Goshems Farm Landfill (HLU0526)	The site is located within the order limits and presents a potentially significant source of pollution to controlled waters and potentially significant source of landfill gas that could impact the Project in the vicinity of the north portal. The potential source are likely to be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage. Results of the ground investigation have indicated the presence of potential heavy metal, asbestos, and PAH soil contamination in the made ground and natural ground. Furthermore, elevated ground gases, vapours, and groundwater	High

Package	Name (HLU)	Discussion from GQRA reports	Refined qualitative risk rating
		contamination has been recorded in the landfill waste and Alluvium beneath the site. Impacts to surface waters and sediment adjacent to the site have also been attributed to the landfill. Therefore. the potential source requires further assessment and possible remedial works/ specific design.	
G	Low Street Landfill (HLU0535)	The site is located within the Order Limits where the route is elevated on viaduct and at proposed intrusive utility works. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Results of the ground investigation identified discrete asbestos soil contamination in the made ground. Therefore, there is a possible plausible pollutant linkage. The potential source requires further assessment and possible remedial works / specific design.	Medium
H	Dansand Quarry (HLU0963)	The majority of the quarry lies adjacent to the Order Limits. The road and proposed utility works run along the northern boundary of the quarry. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Results of the ground investigation have indicated the presence of potential contamination. Results from both soil and leachate analysis recorded exceedances of the GAC for PAH, metals, and inorganics. Asbestos was also detected at low levels within soil samples. Therefore, there is a possible plausible pollutant linkage. The potential source requires further assessment and possible remedial works / specific design.	Medium
I	Welcome Villa (HLU0960)	The former PFS is within the Order Limits and located in an area of proposed intrusive utility works. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may	Medium

Package	Name (HLU)	Discussion from GQRA reports	Refined qualitative risk rating
		be created. Therefore, there is a possible plausible pollutant linkage. No intrusive ground investigation has been undertaken at the site to date. The potential source requires further assessment and possible remedial works / specific design.	
J	Buckingham Hill Landfill (HLU0864)	Records indicate the site was restored with a capping layer, but this is not confirmed. Possible groundwater impacts are suspected. Desk-based information and the results and assessment of gas monitoring undertaken at the landfill suggest adjacent areas of crop growth have been impacted by landfill gas. Buckingham Hill landfill is proposed as a Nitrogen Deposition Compensation Site Intrusive activities may be required to develop the area and as such the potential source may be disturbed by proposed groundworks to develop the Nitrogen Deposition Compensation Site and a pathway may be created. The impact of landfill gas on crop growth requires further investigation. It may also pose a risk to human health receptors from potential direct contact / ingestion of contaminated soil. Therefore, there is a possible plausible pollutant linkage.	Medium
K	Ockendon Grays Areas II & III Landfill (HLU1062)	The majority of the landfill sits outside the Order Limits, with the exception of the northeast and south. Proposed intrusive works cross the northeast of the landfill and the route alignment runs beyond the site's northern boundary. Proposed construction access routes are present in the south. A proposed drainage pond is located immediately to the east. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage. No intrusive ground investigation has been undertaken at the site to date. The potential source requires	Medium Site-specific intrusive ground investigations are required to confirm the contamination status of the site and refined the CSM.

Package	Name (HLU)	Discussion from GQRA reports	Refined qualitative risk rating
		further assessment and possible remedial works.	
L	Potential asbestos containing irrigation pipes, Hall Farm (HLU1151)	The potential asbestos containing pipes are located within the Order Limits. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage. No intrusive ground investigation has been undertaken at the site to date. The potential source requires further assessment and possible remedial works.	Medium Site-specific intrusive ground investigations are required to confirm the location and condition of the asbestos pipe. Appropriate risk communication, health and safety precautions, monitoring and validation sampling are required during the removal of the asbestos pipe.

Other contaminative sources

3.1.5 In addition to Table 3.1, discrete heavy metals, PAH and asbestos soil contamination were identified in localised pockets of made ground or natural ground, in areas where no credible contaminant sources are recorded (e.g., car parks, agricultural fields, etc). These soil contaminants are representative of the made ground, windborne inclusions from unknown sources or cross-contamination.

3.1.6 Visual and olfactory evidence of contamination was occasionally recorded on exploratory hole logs in the form of hydrocarbon odours, stains, and sheens. However, no subsequent laboratory analysis confirmed the presence of hydrocarbons in corresponding soil samples.

3.1.7 Furthermore, elevated ground gases have been detected in Alluvium deposits, particularly where organics soils or peat is present, across the Project route.

Contaminants of concern

3.1.8 The identified contaminants of concern, along with a brief description of their distribution, is summarised below:

a. Heavy metals – discrete locations.

b. Polycyclic aromatic hydrocarbons (PAHs) – discrete locations.

c. Asbestos (visible fragments and fibres) – discrete locations.

d. Ground gases (e.g., carbon dioxide, methane, hydrogen sulphide and carbon monoxide) – widespread.

e. Vapours (e.g., benzene, carbon di-sulphide, hexane, and tetrachloroethene) – discrete locations (Goshems Farm Landfill).

Identified pollutant pathways

3.1.9 Based on the findings of the Preliminary Risk Assessment (PRA) Report (Application Document 6.3, Appendix 10.6) and refined within the Generic Quantitative Risk Assessment (GQRA) reports (Application Document 6.3, Appendix 10.9 Annex A-D), the following pollutant pathways may be present in the Order Limits and may need to be addressed:

a. Direct/dermal contact and incidental ingestion of contaminated soil.

b. Ingestion of soil or wind-blown dust or fibres.

c. Build-up of vapours or gases in confined spaces.

d. Inhalation of vapours, gases or wind-blown dust or fibres.

3.1.10 Whilst groundwater exceedances of controlled water screening values have been recorded, it is considered that the groundwater concentrations encountered are reflective of natural background conditions or up hydraulic gradient contaminative sources located outside the Order Limits. To date, there is no evidence to confirm that leaching contaminants from the made ground soils within the Project are impacting controlled water receptors (e.g., aquifers in the River Terrace Deposits and the Chalk, as well as the adjacent River Thames).

3.1.11 Therefore, this report will primarily look to identify and detail remediation options to manage the risk to human health.

3.1.12 However, given the sensitivity of groundwaters beneath the site and the uncertainty regarding the leaching pathway, this report and wider Project will look to prevent input of pollutants into the water environment (Environment Agency, 2017) and achieve betterment in groundwater quality, through the reduction in infiltration as a result of new road structures, surface water drainage controls and compaction of soils beneath the site.

Identified sensitive receptors

3.1.13 Based on the findings of the PRA Report and GQRA Report, it is considered that following sensitive human health receptors are identified as relevant sensitive receptors in the Project:

a. Construction workers

b. Operational staff

c. Road users

d. Adjacent land users – residents

e. On site and adjacent land users of outside open space

f. Adjacent land users – industrial, commercial and agricultural workers

3.1.14 Although not mentioned in the list above, this report and the Project will look to prevent impact of groundwater quality in the Secondary A

(River Terrace Deposits) and Principal (the Chalk) Aquifers, as well as surface water quality in the River Thames. The Project will look to prevent input of pollutants into the water environment (Environment Agency, 2017) and achieve betterment in groundwater quality, through the reduction in infiltration as a result of new road structures, surface water drainage controls and compaction of soils beneath the site.

Data gaps and uncertainties

3.1.15 The information obtained during the Phase 1 and 2 Ground Investigations is considered to be sufficient to produce a Remediation Options Appraisal and an Outline Remediation Strategy. However, the following data gaps and uncertainties were identified by the PRA Report and GQRA report, which require further consideration and would need to be addressed before any detailed remediation design is done, as required under GS001 of the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2).

a. The contamination status of medium and high-risk credible contaminant sources detailed in Table 3.1 is unknown or not fully characterised due to limitation ground investigation.

b. The laboratory method detection limits for some contaminants of concern have occasionally been recorded as higher than the soil leachate, groundwater, or soil vapour GAC.

c. Discrete soil contamination identified by the ground investigations to date have not been delineated.

d. Some of the exploratory hole positions which were monitored for ground gases were not installed specified for ground gas monitoring and as such their corresponding response zones were flooded. Consequently, there is uncertainty around the recorded concentrations of ground gases.

3.1.16 The above data gaps and uncertainties would be addressed by this report and subsequent future assessments by the Contractor on behalf of National Highways, as required under GS001 and GS027 of the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2).

3.1.17 The sources encountered during the GI works have not indicated gross or widespread contamination. Discrete pockets of soil contamination have been observed, generally associated with made ground.

3.1.18 As stated above, discrete soil contamination identified has not been delineated and therefore the selection of possible remediation options cannot be narrowed down based on the lateral extent of the contamination. The Contractor would need to undertake further intrusive ground investigation to understand the lateral extent of the contamination identified, as required under GS001 of the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2).

4 Remedial options appraisal

4.1 Feasible remediation options

4.1.1 A list of feasible remediation options was produced for each relevant pollutant linkage and is detailed in Annex B.

4.1.2 The exercise identified a range of in-situ and ex-situ biological, chemical, thermal, physical, and civil based engineering remediation options. The exercise was undertaken to identify what remediation technologies were readily available to deal potential contaminants of concern which could be encountered within the Order Limits of the Project.

4.1.3 Given the nature of the contaminants identified by the ground investigations to date, the current land uses and the proposed highway scheme, it is not envisaged that complex in-situ and ex-situ biological, chemical, and thermal remediation methods would be required. Furthermore, as no groundwater contamination to date has been linked to the credible sources along the proposed route, remediation methods specific to groundwater contamination are not considered necessary. Therefore, the following physical and civil engineering-based remediation methods, specific to soil contamination, have been shortlisted for detailed evaluation:

a. Containment (e.g. cover system / capping layer)

b. Excavation and disposal

c. Solidification and stabilisation

4.1.4 It should be noted that the above only addresses the risks associated with soil contamination, not ground gases and vapours. It is considered that the risk associated with ground gases and vapours will be managed by engineering measures through the design of structures and REAC protocols implemented by the Contractor, as required under GS018 of the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2). Some of the potential specific design options likely to be included are structural barriers, passive or active dispersal layers, and gas resistance membranes, with the prevention of preferential pathway being managed through cut off mechanism, such as external clay stanks in utility corridors.

4.1.5 The Contractor will also commission an asbestos management plan and specialist asbestos contractors to manage the risks associated with asbestos in soil, in accordance with CAR SOIL (CL:AIRE, 2016).

4.2 Detailed evaluation of options

4.2.1 The selection procedure for the remediation options appraisal broadly follows the decision making process outlined by Land Contamination: Risk Management 2019 (LCRM 2019) and the Construction Industry Research and Information Association (CIRIA), incorporating guidance raised

by the EA for the selection of remediation strategies. Site specific remediation objectives are broken down into the following areas:

a. Technical Feasibility.

b. Operational Parameters; and

c. Commercial Parameters.

4.2.2 A detailed evaluation of the shortlisted remediation options has been undertaken as presented in Annex C.

4.3 Selected remediation option

4.3.1 Based on the findings, it considered that the most feasible remediation option is likely to be a combination of:

a. Containment.

b. Excavation and disposal.

4.3.2 The selected remediation options are well established remediation methods in brownfield regeneration. The cost and environmental impact associated with disposal can be reduced through the reuse of any impacted soils beneath areas of hardstanding or cover systems.

4.3.3 Leachable contaminants have been recorded in the made ground associated with credible contaminants sources, along the Project Order Limits. Should supplementary investigations confirm pollutant linkages exists between the made ground and groundwaters via the leaching pathway, stabilisation and solidification should be considered, as a contingency.

4.3.4 The above options also meet the objective to retain as much material within the Project as possible with a minimal amount disposed at a waste facility.

4.3.5 Should other potential contaminants of concern, such as petroleum hydrocarbons, non-aqueous phase liquids (NAPL), be encountered in the ground or groundwater during the development works, this remediation options appraisal should be refined to reflect the revised CSM.

5 Assessment criteria

5.1.1 For soils to be remediated or reuse during the development work, specific site assessment criteria (SSAC) should be derived. The SSAC need to be protective of both human health and controlled waters.

5.1.2 To date, no SSAC has been derived for the Project. It is considered that extensive consideration to different scenarios and source material would need to be undertaken to derive site wide assessment criteria. No contaminants of concerns have been identified by the ground investigations, to date, to warrant the derivation of SSAC. Furthermore, final designs for the Project have yet been developed and therefore it would be difficult for SSAC to be relevant.

5.1.3 Following the completion of supplementary ground investigations and detailed design, the Contractor will derive SSAC for the site, that is protective of both human health and controlled waters in accordance with UK best practise and following guidance in LCRM (Environment Agency, 2021) to inform the detailed site specific remediation strategies as required under GS027 of the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2).

6 Preparatory activities

6.1 Supplementary ground investigation

6.1.1 As noted in Table 3.1, the contamination status of several credible contaminant sources along the proposed Route Order Limits with a medium or high-risk rating, have not been fully characterised by intrusive ground investigation to date. The Contractor must undertake supplementary ground investigations to confirm the contamination status of credible contaminant sources and refine the CSM, as required under GS001 of the Register of Environmental Actions and Commitments (REAC) ((Code of Construction Practice (Application Document 6.3, Appendix 2.2).

6.1.2 Should unexpected discrete gross contamination (e.g., asbestos, hydrocarbons, etc) be encountered during the supplementary ground investigation, the Contractor shall delineate the contamination hotspot to inform remediation costs and the most suitable remediation options.

6.2 Detailed quantitative risk assessment (DQRA)

6.2.1 Following the supplementary ground investigation, should the associated GQRA identified potential human health and/or controlled water risks that cannot be managed through the adoption of standard protocols detailed in the REAC, the Contractor must commission a specialist risk assessor to undertake a DQRA to derive SSAC and facilitate the remediation and/or reuse of soils.

6.2.2 The specialist risk assessor shall select appropriate parameters from site-specific information and published parameters, risk assessment models compatible to the CSM and include a sufficient sensitive analysis of site-specific parameters.

6.3 Detailed remediation design

6.3.1 Following the completion of supplementary ground investigations by the Contractor, detailed remediation designs should be undertaken, where necessary, to encompass all elements and provide a detailed description of the extent of remediation required, soil stockpiling, validation testing, programme, and integration with earthworks.

6.4 Materials management plan

6.4.1 The Contractor shall prepare or commission a Materials Management Plan (MMP), in accordance with the Definition of Waste Industry Code of Practice (DowCoP) (CL:AIRE, 2011), or other environmental mechanisms, to allow the reuse of site-won soils or soils from cluster hub sites.

6.4.2 Before works commenced on site, a Qualified Person shall approve the MMP by completing and submitting a declaration to CL:AIRE.

6.4.3 The tunnel alignment and intrusive utility works are planned within the boundary of the Goshems Farm Landfill (HLU0526). Excavated soils from this landfill being considered for reuse would fall outside scope of the DoWCoP. Should excavated landfill soils be considered for reuse, the

Contractor must prepare a Waste Recovery Plan (WRP) to support an environmental permit (Environment Agency, 2021).

6.4.4 The MMP and WRP should be followed throughout the construction phase. This would include the management of soil arisings created by piling, foundation construction and groundworks, excavation of utility corridors or reducing levels to accommodate capping layers in landscaping. The movement and re-use of such materials should be recorded within the MMP or WRP, and subject to verification in accordance with this remediation strategy.

6.5 Remediation method statements

6.5.1 The Contractor shall prepare method statements prior to the implementation of the site-specific remediation strategies which should include a description of methods to be applied for materials movement, asbestos management, unexploded ordnance, environmental management, verification, groundwater / surface water control and treatment, and well decommissioning.

Asbestos management plan

6.5.2 Both asbestos fibres and visible fragments have been identified during the ground investigations within the Order Limits of the Project. Therefore, an asbestos management plan will be commissioned before the remedial works to outline the following:

a. The locations of asbestos soil contamination within the Project Order Limits.

b. The licensing status of future intrusive works at the locations of asbestos soil contamination.

c. Identity of relevant duty holders (e.g., landowners, site mangers, local authorities, etc).

d. Recommended remediation measures to mitigate the current risk to site users, and where appropriate, reduce the asbestos content in soils.

e. Recommended asbestos control measures for future intrusive works (e.g., dust suppression, reassurance air monitoring, respiratory protection equipment, etc.).

6.5.3 The asbestos management plan should be distributed to the relevant duty holders, incorporated into the construction plan phase, and then into the health and safety file thereafter. The plan should be prepared in accordance with CAR SOIL (CL:AIRE, 2016).

Monitoring Action Plan

6.5.4 Elements of the development works may cause a change in the ground gas, vapour, groundwater, and surface water regimes in particular areas, and the risk to sensitive receptors could increase. Therefore, a monitoring action plan will be developed for the enabling and construction phase works, with threshold triggers set, which are compatible with the nature of the work being undertaken,

the ground gas and vapour regime, the underlying groundwater vulnerability and/or adjacent surface water receptors.

6.5.5 The monitoring action plan should look to ensure:

a. The ground gas and vapour risks are communicated to the project team and incorporated into the health and safety file for the project.

b. Existing monitoring installations are maintained, protected or supplementary, as required, during the development works.

c. Monitoring installations designated as redundant are decommissioned before the development works commence, in accordance with EA guidance, to prevent contaminant migration via preferential pathways.

d. A programme of gas monitoring of ground gas and vapours, ambient air and the general working environment is undertaken, to comply with Health and Safety regulations and HSE EH40 Workplace Exposure Limits (HSE, 2020), during the enabling and construction phase works.

e. Gas monitoring and subsequent ventilation for extraction of groundwater control systems during the enabling and construction phase works.

f. Consideration is given to ongoing monitoring and sampling soil gas at surface, near-slab, sub-slab, utility installations and/or at point of exposure within temporary accommodation, during the enabling and construction phase works, following detailed risk assessment.

g. Thematic maps are produced for the wider route to identify areas of elevated ground gas risk and assess the Characteristic Situations to be applied to structures and infrastructure.

h. A programme of groundwater and surface water monitoring is undertaken, in tandem with the ground gas and vapour monitoring, if possible, during the enabling and construction phase works.

6.5.6 Further information on the monitoring programme, the protection and decommissioning of monitoring installations is provided in section 8.

6.6 Foundation works risk assessment

6.6.1 Below ground structures will be formed such as piles for bridge abutments and embankments and for ground improvement works. This activity could cause an impact on the underlying geology and hydrogeology as a vertical pathway could be created for the migration of contaminants to underlying aquifers or the migration of ground gas/ vapour to humans or property.

6.6.2 A site-specific Foundation Works Risk Assessment (FWRA) will be undertaken prior to construction and agreed with the EA to confirm the appropriate construction method. This is committed to in the REAC (REAC GS026).

6.6.3 The FWRA would be completed in line with Environment Agency document: Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention NC/99/73 (Environment Agency, 2001).

6.6.4 During the preparation of the FWRA, different pollution scenarios as defined in the EA guidance would need to be considered. Consideration would also be given to the environmental sensitivity of the area where the activity is taking place, such as the aquifer status (SPZ), if area is contaminated.

6.7 Licensing and permitting

6.7.1 Any licences and permits required for remediation and earthworks activities, such as screening soils and abstracting groundwater, shall be obtained in advance of the remedial works.

7 Outline remediation strategy

7.1 Overview of works

7.1.1 The following activities are anticipated to take place as part of the remedial works:

a. Establishment of site compounds.
    i. Baseline monitoring.
    ii. Decommissioning of redundant monitoring installations (see section 8).
    iii. Non-native invasive plants.
b. Soft strip.
    i. Provision of access.
c. Temporary works.
d. Break-up of hard surfaces.
e. Demolition of existing buildings and relic-structures.
f. Decommissioning and removal of fuel storage tanks.
    i. Re-route underground or above ground services.
g. Processing of hard materials.
h. Excavation and removal asbestos containing pipe.
i. Earthworks.
j. Management of unexpected contamination.
    i. Construction of highway, bridges, retaining walls, bored tunnel, and attenuation ponds.
k. Utility corridors.
l. Groundwater management.
m. Installation of ground gas and vapour measures.
n. New landscaping areas.

7.1.2 Some of the above actions (highlighted in **bold**) are described in further detail below.

7.2 Establishment of site compounds

7.2.1 Site compounds shall be established on level ground and cause minimum damage to the environmental and ecological receptors. Minor earthworks / ground improvement may be required to facilitate a temporary platform the site compound.

7.2.2 Given the presence of elevated ground gases and vapours within the Package B area, site accommodation, including temporary sleeping quarters, offices, canteens, and storage containers, shall be designed, and set up to prevent the building and ingress of ground gases and vapours, in accordance with British Standard BS8485:2015+A1:2019 (British Standards Institution, 2019) and The VOC Handbook, CIRIA C682 (CIRIA, 2009). Temporary ground gas and vapour protective measures are likely to comprise structural barriers, passive or active dispersal layers and maybe gas resistant membranes beneath site accommodations, sealed service ducts and gas/vapour alarms. Further information is provided in subsection 7.14.

7.2.3 Appropriate hoarding and signage shall be set up along the perimeter of site compounds, and the main work construction areas.

7.3 Soft strip

7.3.1 Topsoil from greenfield areas of the site shall be stripped before construction commences in line with the Project wide Soil Resources Plan and Earthworks Specification. Excavated topsoil shall be retained on Site and re-used during restoration of the area after construction activities have ceased. The soils shall be handled and managed in accordance with industry good practice.

7.4 Temporary works

7.4.1 Delivery of the remediation works is likely to require some elements of temporary works particularly where excavations extend within proximity of surface watercourses. This will be the responsibility of the Contractor and their supply chain on behalf of National Highways.

7.5 Break up of hard surfaces

7.5.1 Tarmacadam/asphalt bound materials shall be segregated and stockpiled separately to Made Ground and soils. The tarmacadam/asphalt stockpiles shall be tested for a speciated PAH suite. Material with benzo(a)pyrene concentrations above 50 ppm (mg/kg) shall either be stabilised or treated prior to re-use within the scheme under an appropriate Environmental Permit or disposed of at an appropriate waste disposal facility. Material with benzo(a)pyrene concentrations below 50 ppm (mg/kg) shall be re-used following the WRAP Aggregate Quality protocol (Environment Agency, 2013) and EA Regulatory Position Statement (RPS) 75 (Environment Agency, 2014).

7.5.2 Hardstanding materials derived from concrete hardstanding shall be crushed in accordance with an appropriate specification.

7.6 Demolition of existing building and removal of relic structures

7.6.1 Demolition appraisals will be undertaken by the appointed demolition contractor incorporating a desk study review, site inspection, and consultations with the property owner to inform the risks, including the potential for encountering below ground fuel tanks (either permitted or undeclared) and presence of asbestos containing materials. An appropriate demolition method statement shall be developed accordingly by the appointed demolition contractor.

7.6.2 Prior to demolition, all asbestos containing materials, where practical, shall be removed by a specialist contractor, with appropriate verification documentation (e.g., removal report, consignment notes and reassurance air monitoring records) retained by the Contractor.

7.6.3 Relic sub-structures and foundations shall be excavated and removed from the main work construction area.

7.7 Decommissioning of fuel storage tanks

7.7.1 Any above and below ground fuel storage tanks shall be decommissioned and removed in accordance with guidance outlined in the Association for Petroleum and Explosives Administration (APEA) and Energy Institute's design, construction, modification, maintenance and decommissioning of filling stations, 4th edition (APEA and Energy Institute, 2018).

7.7.2 The tanks shall be decommissioned and removed offsite by a suitably qualified contractor. Elements of tanks shall be recycled, treated, or disposed offsite to an appropriately licensed waste management facility.

7.7.3 Any residual ground or groundwater contamination shall be remediated accordingly, followed by post-remediation groundwater, ground gas and vapour monitoring.

7.8 Processing of hard materials

7.8.1 Stockpiled hard materials from the demolition and grubbing up works shall be crushed and screened to remove any unsuitable elements, in accordance with an appropriate specification. The resultant source segregated aggregates shall be stockpiled for reuse during the construction works.

7.8.2 A ground engineer shall assess the suitability of the source segregated aggregates for reuse, instruct the removal of any unsuitable material and schedule appropriate confirmatory geotechnical and/or geo-environmental laboratory analysis.

7.8.3 An overall bulking factor following crushing and compaction shall be adopted in line with the Earthworks Specification.

7.9 Excavation and removal of asbestos containing pipe

7.9.1 It is understood that an asbestos containing pipe runs across the main route alignment in Package D and poses a risk to construction workers.

7.9.2 The location of this pipe shall be confirmed using non-intrusive surveying techniques (e.g., ground penetrating radar) and as-built drawings provided by the landowner.

7.9.3 The pipe shall be excavated by a specialist asbestos contractor, with the resultant excavation validated for residue asbestos fibre contamination.

7.9.4 If possible, visible asbestos fragments should be hand-picked and segregated from soil matrix in arisings.

7.9.5 The visible asbestos fragments shall be damped, doubled bagged, sealed, and disposed offsite at an appropriately licensed hazardous landfill.

7.9.6 The remaining soil arisings found not to contain visible asbestos fragments shall be transported and temporarily stockpiled to await assessment for reuse or offsite disposal.

7.10 Earthworks

Excavation of soils

7.10.1 Soils shall be excavated from the main route alignment cutting areas and utility work areas, across the Project.

7.10.2 Excavated soils are expected to comprise made ground and natural soil / contaminated and uncontaminated soils.

7.10.3 Hotspots of soil contamination identified by the Contractor's supplementary ground investigation shall be subjected to targeted excavation by a specialist remediation contractor.

7.10.4 Excavated natural/ uncontaminated soils shall be segregated from other soils and designated for reuse in fill areas of the Project or temporarily stockpiled.

7.10.5 Excavated made ground/ contaminated soils and reworked natural soils shall designated for assessment at soil processing compound at the Project.

Transport of soils

7.10.6 Soils shall be transported from excavations to placement or stockpiled areas, within the Order of Limits of the Project.

Stockpiling of soils

7.10.7 Temporary stockpiling of soils will be required to permit effective programming of plant and personnel.

7.10.8 The Contractor shall locate stockpiles a minimum of 10m away from waterways. Stockpiles shall also be kept away from stopes that are subject to failure, considering gradient and height accordingly (CIRIA, 2015).

7.10.9 The Contractor shall ensure that any stockpile that will be used on site for a long period be profiled appropriate and vegetated to improve its stability and aesthetics. Stockpiles shall be dampened to prevent dust generation during dry periods and covered to prevent rainwater ingress. Surface run-off can be controlled through bunding, vegetation, silt fencing and through the use of cut-off trenches (CIRIA, 2015).

7.10.10 Should it be envisaged that the use of materials will occur more than one year from being stockpiled or stored, the Contractor shall agree a time limit with the Environment Agency, and detail within the relevant MMP. In this instance, the Contractor may be requested to provide supporting information, in the form of site plans, cross sections and stockpile control measures to the Environment Agency (CL:AIRE, 2011).

7.10.11 Separate areas should be designated for stockpiles of excavated made ground and natural soil / contaminated and uncontaminated soils. Made ground / contaminated soils should be stored on impermeable material to prevent leaching (i.e., from metals and organics into groundwater).

7.10.12 The soils will be visually inspected, sampled, and assessed in accordance with the Contractor's SSAC and Earthworks Specification. Following the assessment exercise, the soils shall either be assigned to be reused, treated, or disposed offsite.

Placement of suitable soils

7.10.13 Soils considered suitable for reuse should be placed in designed fill areas.

7.10.14 The soils will be placed and compacted in accordance with the Contractor's geotechnical specification and/or Earthworks Specification, to create the required topographic contours.

Disposal of contaminated or unsuitable soils

7.10.15 Visible asbestos fragments and/or asbestos fibre contaminated soils shall be disposed in accordance with the asbestos management plan.

7.10.16 Further testing may be required (e.g., hazardous waste classification and waste acceptance criteria) to ensure that the appropriate waste classification is determined and therefore the appropriate facility. The waste producer has the Duty of Care for the appropriate disposal of waste soils / materials.

7.11 Management of unexpected contamination

Discover strategy and watching brief

7.11.1 A general watching brief should be undertaken during construction works, and during any further ground investigation. If visual / olfactory evidence of contamination is encountered e.g., staining, odours, fibrous materials, free product, appropriate analysis should be undertaken to confirm if the soil meets the required criteria to be protective of human health and controlled waters.

7.11.2 If concentrations above the criteria are encountered, further investigation and chemical testing may be required to delineate areas impacted. Assessment of the significance of such finds would need to be made.

7.11.3 Current site investigation information should be included within the Contractor's Health and Safety risk assessment and method statement for the works. This should include measures such as appropriate use of personal protection equipment (PPE) and dampening stockpiles of excavated material to prevent dust generation. Construction workers should be briefed to be extra vigilant during the works.

7.11.4 Should potential contamination not previously identified be encountered, a suitably experienced Geo-environmental Engineer should be contacted to assess the potentially contaminated material to determine the risks present and the appropriate cause of action. If the contamination is encountered is considered to present an unacceptable risk to human health or the environment without further mitigation, it must be reported as soon as reasonably practicable to the Secretary of State, the relevant planning authority and the Environment Agency, and the contractor must complete a risk assessment of the contamination in consultation with the relevant planning authority and the Environment Agency (as per Requirement 6 of the DCO). Any required remedial works are to be agreed with the relevant parties and implemented as approved.

7.11.5 Details of the watching brief, evidence of contamination and actions taken should be recorded and documented for inclusion in the final Verification Report. Additional chemical analysis and assessment of soils suspected of being contaminated may be required to ensure that the appropriate action is undertaken. Contractors involved with excavation works on Site would be briefed as to the potential presence of land, water, or airborne contamination before commencing work. Details of the potential presence of contamination and health and safety measures would form part of the Contractor's Health and Safety Documentation for the works.

Soil contamination

7.11.6 Should visible asbestos containing materials (ACM) be encountered during excavations, the Contractor shall follow the steps outlined in the discovery strategy, and the commissioned asbestos management plan as per section 6.5.

7.11.7 Soils found to contain visible asbestos containing materials and therefore unsuitable for immediate reuse should be subjected to asbestos hand picking, in accordance with the Contractor's asbestos management plan.

7.11.8 If identified during the watching brief, discrete anthropogenic materials such as concrete, brick, glass, plastic, clinker etc., or material which has visual / olfactory evidence of contamination, must be segregated as necessary from the 'reworked natural' Made Ground, i.e., made ground which contains little to no anthropogenic material, and appears to be reworked/disturbed natural material.

7.11.9 If present, any recoverable metal, glass, and plastics collected from made ground would be segregated and, where possible, recycled off-site at a suitable licensed facility.

7.11.10 If encountered during earthworks, organic soil contamination must be segregated and stockpiled in appropriate laydown areas incorporating leachate collection systems. The organic soil contamination shall be subject to laboratory analysis to confirm the contaminant of concern and identify the most suitable remediation option. The Contractor must prepare an addendum to the specific remediation method statement.

7.11.11 Given that the unexpected organic soil contamination will likely be encountered during excavation works, it is considered some form of ex-situ biological, chemical or physical treatment method would be most appropriate, subject to regulatory approval and batch/ field trials.

7.11.12 Following ex-situ treatment or asbestos hand picking, the resultant soils should be screened against the Contractor's SSAC prior to reuse beneath hardstanding or cover systems.

Groundwater contamination

7.11.13 There is potential that contaminated groundwaters may be encountered by the Contractor during excavation and dewatering works. Therefore, the Contractor must make an allowance to treat and/or dispose contaminated groundwaters during the development works.

7.11.14 Perched groundwater contamination must be addressed as part of a wider perched groundwater management programme during the bulk soils turnover works.

7.11.15 Where gross contamination is found extending to the water table, efforts must be made to extend excavations partially below the water table, where feasible to do so, to facilitate mass pumping and recovery of contaminated groundwater mass during the turnover activities.

7.11.16 If Non-Aqueous Phase Liquid (NAPL) is encountered in relation to groundwater, physical recovery, and subsequent disposal of the NAPL would be required. The nature of the NAPL recovery would depend on a number of factors but could comprise:

a. NAPL only recovery through skimming techniques if sufficient recoverable quantities are found; or

b. In the instance that NAPL is present uncoalesced blobs or ganglia, the removal of NAP through total fluid recovery should be considered. This could be enhanced with the application of vacuum, heat, or surfactants, where required.

7.11.17 Any visually or olfactory contaminated abstracted groundwater, identified as part of the watching brief outlined in section 7.11.1, shall be temporary stored in intermediate bulk containers (IBCs) or larger steel storage tanks, sampled and tested to confirm its waste classification. Subject to the laboratory results, the abstracted contaminated groundwater must either be treated prior to discharge to foul sewers or removed offsite to an appropriate wastewater treatment facility.

7.11.18 The Contractor shall prepare addendum to their specific remediation method statement and consider the groundwater treatment technologies outlined in CIRIA C750, Groundwater control: design and practice (CIRIA, 2016).

7.11.19 Volumetric records of any water and free phase hydrocarbons recovered and treated from excavations shall be retained by the Contractor. Laboratory analysis of recovered groundwater / treated groundwater shall also be retained to support off-site disposal, re-infiltration, or disposal under consent to foul drainage network.

7.12 Groundwater management

7.12.1 A number of structures will be required to deliver the Project, including bored tunnels, culverts, retaining and diaphragm walls, etc, and these are likely to require groundwater drainage due to their depth of construction.

7.12.2 Given the soil and groundwater exceedances recorded during the ground investigations, groundwater drainage maybe contaminated, and the Contractor must make an allowance for suitable management and mitigation measures, together with appropriate and regulatory approval.

7.12.3 The design of specific structures and features on site must allow for the management of contaminated groundwaters.

7.12.4 Given the ground gas regimes in the Packages A and B areas and the potential for degassing from pumped water, groundwater control systems should incorporate gas ventilation and extraction measures to prevent accumulation of gases.

7.13 Utility corridors and drainage networks

7.13.1 Proposed utility corridors and drainage networks are anticipated to be placed through made ground, peat, and areas of soil contamination. Therefore, the Contractor must ensure that construction workers and future maintenance workers are protected from contaminated soil, and groundwaters. Utility corridors and drainage networks must be excavated and backfilled with soils suitable for use to limit future interaction with residual soil contamination.

7.14 Ground gas and vapour protection measures

7.14.1 Elements of the development works may cause a change in the gas regime in particular areas. For example, in the area of the north portal the dewatering activities required to construct the portal may cause ground gases and vapours to be released due to the lowering of the saturated zone. This could in return cause a change in the gas regime in the area of the accommodation on Northern Tunnel Entrance Compound which is located adjacent to the north portal.

7.14.2 The risks from ground gases and vapours shall be communicated to site operatives through health and safety site inductions and toolbox talks.

7.14.3 The Contractor must ensure all excavation, penetrative and confined space works (e.g., utilities, drainage, and bored tunnel) are actively monitored for ground gases and vapours, and appropriate RPE is provided to site operatives where necessary. Active monitoring is likely to include the provision of personal alarms in areas known to be impacted by ground gases and vapours. These measures are in line with commitments in the REAC (Ref. GS023).

7.14.4 Groundwater control systems should be designed to incorporate the ventilation and prevent the accumulation of ground gases and vapours, during dewatering exercises.

7.14.5 Consideration should be given to the adoption of explosion proof and intrinsically safe equipment during earthworks activities (CIRIA, 2016).

7.14.6 It is envisaged that temporarily site accommodation may need to incorporate a suspended subfloor, passive, or active dispersal layers, and potentially gas / vapour resistant membranes (British Standards Institution, 2019). The active dispersal layers rely on continued serviceability of pumps, consequently, alarm and response systems may need to be in place.

7.14.7 A post earthworks ground gas and vapour validation exercise will be required to establish the ground gas and vapour regimes following completion of the earthworks. It would form part of the construction phase to confirm the risks and design, install and verify suitable gas and vapour protection measures, where required, for structures proposed across the Project.

7.14.8 Where ground gas and vapours protection measures are required, the design must be in accordance with British Standard BS8485:2015+A1:2019 (British Standards Institution, 2019). All ground gas and vapour protection measures incorporated into the design of the structures shall be documented on site by the Contractor.

7.14.9 In respect to the bored tunnel and similar underground structures, the floors and walls shall conform to BS 8102:2009 and benefit from Grade 2 or 3 waterproofing (British Standards Institution, 2009) in order to resist the ingress of water and dissolved phase gases. Furthermore, the structure must be designed to vent future car exhaust fumes, ground gases and vapours in accordance with Building Regulations 2010, Approved Document F (HM Government, 2010).

7.14.10 In addition, utility and drainage corridors may act as preferential pathways for ground gases and vapours. Therefore, where relevant or reasonably practicable, these corridors must be designed with mitigation measures incorporated (e.g., external clay stanks and internal baffles or bulk heads) to prevent gas migration (Application document 6.3, Appendix 10.9). Consideration shall be given to regularly spaced ventilation of normally confined or semi-confined spaces.

7.14.11 In areas with high ground gas risk regimes, hard surface finishes must be designed to promote passive ventilation of ground gases and vapours, so they are dispersed to the atmosphere (Application document 6.3, Appendix 10.9).

7.15 New Landscaped Areas

7.15.1 The Contractor shall ensure that newly created landscape areas have a suitable thickness of clean cover soils above any contaminated soils. Where asbestos fibres or visible fragments are known to be present, a marker layer (geotextile) must be placed between the underlying made ground and the cover soils.

7.15.2 The material is required to meet the requirements of cover material classification, which includes:

a. Compliance with the GAC for a proposed park/open space scenario.

b. Landscape architect requirements.

c. Earthworks Specification.

7.15.3 Where landscaping is placed directly on to natural or reworked natural materials, then subject to suitable verification testing, professional judgement must be applied to reduce capping layers and thicknesses recognising the absence of direct contact risks these soils may represent.

7.15.4 The use of topsoil and subsoil within capping layers must be in accordance with BS 8601:2013 (British Standards Institution, 2013) and BS 3882:2015 (British Standards Institution, 2015).

8 Verification plan

8.1 Outline

8.1.1 This section sets out the verification processes that will be undertaken to demonstrate that the risks identified by the ground investigations will be reduced to meet the agreed remediation criteria and objectives, based on a quantitative assessment of the remediation performance.

8.2 Regulatory approval

8.2.1 Remediation works are likely to require regulatory sign-off to ensure that the works have been implemented in compliance with the agreed remedial strategy.

8.3 Sampling and validation

8.3.1 A programme of monitoring, sampling and analysis will be carried out by the contractor for the duration of the remedial and construction works, including:

a. Sampling of excavated soils to classify materials in accordance with a Materials Management Plan or an Environmental Permit.

b. Sampling of imported materials, where required.

c. Collection of groundwater and surface water samples to confirm the construction works have not adversely affected controlled waters.

d. Ground gas monitoring.

e. Vapour monitoring.

f. Discharge monitoring, if required as part of the groundwater management approached adopted by the contractor.

g. Atmospheric monitoring of fugitive dusts (including asbestos).

h. Noise monitoring related to equipment and working methods.

8.4 Soil validation sampling general procedure

8.4.1 Validation sampling will be undertaken by the contractor in accordance with British Standard BS 10175:2011+A2:2017 (British Standards Institution, 2017) and EA guidance, following the principles outlined below:

a. Minimise risk for cross contamination of samples both during sampling and transit.

b. Every sample would have a unique name/ reference.

c. Store samples in clean, laboratory supplied vessels.

d. All samples should be labelled, stored appropriately, and transported under chain of custody to the laboratory.

8.4.2 The contractor would submit all validation samples to an UKAS and MCERTS accredited laboratory.

Soil Sampling Criteria

8.4.3 Geo-environmental and geotechnical testing will be required as part of the validation strategy. Geotechnical testing requirements will be specified within a separate Earthworks Specification.

8.4.4 Validation soil sampling would also be required contamination hotspots, areas of unforeseen ground contamination and material being imported onto the Project. Limits of detection must be appropriate to the analysis being undertaken to provide confidence that concentrations fall below the agreed validation criteria.

8.4.5 A summary of soil validation requirements is outlined in Table 8.1.

Table 8.1 Summary of soil validation requirements

Activity	Performance criteria	Documented evidence for completion
Removal of contaminated soils.	Validated base and sides of excavation meet the remediation criteria.	Field screening/ on-site analysis of soils. Laboratory test data below or confirms 95th percentile concentrations pass the remediation criteria. As built drawings of excavations. Volumetric records of removed material. Reassurance air monitoring records. Photographic record.
Treatment and reuse of contaminated soils.	Treated soils meet remediation criteria or removed from site.	Laboratory test data below or confirms 95th percentile concentrations pass the remediation criteria. Record of where treated soils were placed or removed to. Records of required backfilling and compaction processes. In-situ geotechnical testing of reinstated material to ensure compliance with Earthworks Specification. Volumetric records of reused materials. Reassurance air monitoring records. Photographic record. Waste transfer documentation, tipping register and sample disposal tickets for soils removed.

Activity	Performance criteria	Documented evidence for completion
Earthworks and source segregated aggregates re-use	Materials are suitable for intended use	Laboratory test data demonstrates materials meet acceptance criteria. Record of where treated materials were placed. Records of required backfilling and compaction processes. In-situ geotechnical testing of reinstated material to ensure compliance with Earthworks Specification. Volumetric records of reused materials. Photographic record. Waste transfer documentation, tipping register and sample disposal tickets for soils removed.

8.4.6 The contractor must include, within the remediation method statements, details for the collection of the validation samples. Depending on the source of any imported materials, the frequency of sampling may need to be revised or increased. This should be agreed with the regulators prior to bringing material on to the Project.

8.4.7 Soil validation frequencies and geotechnical criteria for each of the materials classified in the Materials Management Plans or Waste Recovery Plans should be confirmed by the contractor.

Soil Sampling Frequency

8.4.8 Table 8.2 sets out the requirements for the frequency of soil sampling during remediation. The final soil sampling frequency will be defined within the contractor's remediation method statement. The sampling frequency as laid out in Table 8.2 are provided as minimum requirements.

8.4.9 Depending on the source of any imported materials, the frequency of sampling may need to be revised or increased. This should be agreed with the regulator prior to bringing material on to site.

Table 8.2 Chemical testing frequency for remedial works (minimum requirements)

Scenario	During excavation	At the edge of excavations	At the base of excavations	Prior to reuse following processing/ treatment*
Contaminated soil excavation	1 per 500m^2/ 500m^3	1 test per 20m length	20m testing grid	1 per 250m^3
Made ground from cuttings for land raising	1 per 1000m^2/ 1000m^3	-	-	1 per 1000m^3
Natural soil from cuttings for land raising	1 per 1000m^2/ 1000m^3	-	-	-

Scenario	During excavation	At the edge of excavations	At the base of excavations	Prior to reuse following processing/ treatment*
Cover material and clean cover capping layer	1 per 500m^2/ 500m^3	1 test per 20m length	20m testing grid	1 per 250m^3
Imported materials	-	-	-	1 per 1000m^3
Asphalt (prior to removal)	-	-	-	1 per 125m^3

** – Reuse of soils from excavations assumes soils have been subject to some form of treatment.*

8.5 Asbestos Monitoring

8.5.1 During the demolition of existing structures and earthworks in areas of made ground, asbestos reassurance monitoring should be undertaken by a suitably qualified asbestos operative, accordance with CAR 2012 (HSE, 2013), CIRIA C733 (CIRIA, 2014), and CAR SOIL (CL:AIRE, 2016).

8.5.2 Reassurance monitoring should be continuous during the demolition works and on a daily basis during the earthworks. The reassurance monitoring can be gradually reduced during the earthworks following a prolong trend of negligible fibre detections in the air.

8.5.3 The records of the asbestos reassurance monitoring should be retained by the Contractor and included in the subsequent verification report.

8.6 Groundwater and Surface Water Monitoring

Groundwater monitoring

8.6.1 A groundwater monitoring programme will be required for the duration of the construction works. The Contractor shall select a suitable number of existing monitoring installations to be retained and used to provide an ongoing benchmark of groundwater quality throughout the construction works.
The length and frequency of the monitoring programme shall be defined by the Contractor. The groundwater monitoring programme will be subject to agreement with the regulatory authorities.

8.6.2 Additional monitoring wells may be required to delineate discrete area of organic groundwater contamination. The requirement for the addition of further monitoring wells will be considered on the following basis: The location of alternative or additional monitoring well locations will be subject to agreement with the regulatory authorities.

a. Where unexpected soil contamination extends below the water table and there is insufficient groundwater quality data in the immediate vicinity.

b. Where NAPL or gross dissolved phase contamination is encountered during excavation works.

8.6.3 All new and existing boreholes should be co-ordinated prior to the commencement of the groundwater monitoring.

8.6.4 Given the phased nature of the Project, it would be necessary to assess the need for ongoing monitoring on an annual basis, following consultation and agreement with the regulatory authorities.

Surface water monitoring

8.6.5 Monitoring of surface watercourses and other bodies may be necessary throughout the earthworks and following completion of the Project, subject to agreement with the regulatory authorities. In respect to surface watercourses, sample locations, detailed in the Contractor's remediation method statement, shall be upstream, downstream, and midstream of the proposed Project works and agreed with the Environment Agency in advance of the works. The length and frequency of the monitoring programme shall be defined by the Contractor.

Testing requirement

8.6.6 Testing requirements for field measurements and chemical analysis of groundwater and surface water samples shall be defined by the Contractor following consultation and agreement with the regulatory authorities.

8.6.7 Further refinement of the chemical testing suites shall be considered following the completion of further ground investigation and baseline monitoring, as well as following agreement with the approach and outcomes by all project stakeholders.

Borehole retention and modification

8.6.8 For the duration of the construction works, retained boreholes will need to be protected by concrete manhole rings. In the event that a borehole becomes compromised or is lost, a replacement well will be drilled as close as possible to the original location.

8.6.9 Due to the proposed elevation changes and areas of cut and fill along the main route alignment, a number of boreholes will require modifying in order to maintain the monitoring network following the re-profiling of the main works construction area. This can be achieved by extending the standpipe to the required height and casing the well with a suitably protective material or decommissioning and replacement of the borehole. Following re-profiling works and borehole modification, the boreholes will be co-ordinated and levelled at their finished levels in order to maintain the groundwater level modelling. The protection and modification programme shall be repeated throughout, where deemed necessary.

Borehole decommissioning

8.6.10 Following agreement of the groundwater monitoring plan, monitoring wells not required for this programme shall be decommissioned in accordance with Environment Agency Environment Agency (2012) guidance note 'Good Practice for decommissioning redundant boreholes and wells', ref. LIT 6478 / 657_12, dated October 2012.

Reporting

8.6.11 An annual monitoring report would be produced detailing monitoring data from each visit undertaken during the year. Each report would include an interpretation of the data, including any noticeable trends observed, particular in relation to contamination distribution and water quality associated with fluctuations in groundwater levels or site activities. A final completion report would be issued once all monitoring works have been completed.

8.7 Gas Monitoring

8.7.1 Ground gas and vapour monitoring shall be undertaken in accordance with the Contractor's monitoring action plan, as per section 6.5.5.

Site accommodation

8.7.2 At commencement of the construction works, receptor monitoring instrumentation (e.g., indoor or subfloor void monitors) shall be installed within site accommodation, in areas of high-risk areas, to record the accumulation of ground gas or vapours. The monitoring must take place during both the daywork and evening to identify any trends. The frequency of the monitoring must be initially continuous/ high, reducing with time if negligible gas concentrations are recorded.

8.7.3 The receptor monitoring instrumentation shall be synced to alarms in order to alert and evacuate site personnel when toxic or explosive gas conditions are recorded.

8.7.4 The result of the receptor monitoring must be documented and included within annual monitoring and subsequent verification reports.

Field works

8.7.5 Mobile and personal gas monitoring and alarm devices must be in place during intrusive works, in areas of elevated ground gas and vapour risk.

8.7.6 Site diaries must record hourly ground gas and vapour readings and documented any evacuations during gas alarms.

Ground gas regime

8.7.7 As with the groundwater monitoring strategy, the existing selection of ground gas monitoring installation shall be used to characterise the changing ground gas regimes throughout the construction works. The location of alternative or additional monitoring well locations will require Stakeholder agreement.

8.7.8 The ground gas and vapour monitoring programme shall be undertaken concurrently with the groundwater monitoring programme to determine if changes in groundwater levels influence ground gas regimes.

8.7.9 Ground gas monitoring wells must be protected, like the groundwater monitoring wells, by concrete manhole rings. Where monitoring wells become compromised or are lost, replacement wells shall be drilled as close as possible to the locations.

8.7.10 Monitoring wells would also require modification in order to maintain the monitoring network following the re-profiling of the main construction works areas.

8.7.11 Following the completion of the ground gas and vapour monitoring programme, monitoring wells must be decommissioned in accordance with Environment Agency guidelines.

8.7.12 Annual ground gas and vapour monitoring reports shall be produced in tandem with the annual groundwater monitoring reports, with appropriate interpretation of the data relation to fluctuations in groundwater levels and site activities. A final completion report must be issued once all monitoring works have been completed.

8.8 Remediation progress reports

8.8.1 Throughout the remediation works, progress report must be prepared on completion of key milestones. These reports should include:

a. Progress of activities compared to the planned programme and any potential delays.

b. Results of ongoing verification testing against remediation objectives.

c. Results of environmental monitoring against agreed standards.

d. Evidence of compliance with permits or other regulatory controls.

e. Any changes to site supervision and site works.

f. Any requirements to modify remediation.

g. Details of any reported health and safety breaches.

h. Details of any environmental accidents or incidents.

i. Details of site visits made by regulators.

j. Photographic records.

k. Spend compared to planned budget and forecasts.

8.9 Verification Report

8.9.1 A post-remediation verification report must be produced in line with LCRM guidance (Environment Agency, 2021) and other guidance referenced above. The report must contain all site data including analysis results, approvals, licenses, and drawings to show the effectiveness of the remediation.

8.9.2 The verification report shall include the following information:

a. details of the objectives for the remediation strategy selected and a description of the selected project team and their roles and responsibilities.

b. all background information, referencing key supporting documents including this report.

c. a clear description of the remediation work undertaken with details of the sequence of events verification sampling undertaken and results of monitoring work.

d. documentation of actions taken where any unforeseen contamination was encountered.

e. details of methodologies for verification, data collection and interpretation.

f. the final volumes and nature of any materials excavated, treated, and imported will be detailed. Supporting documentation (tip tickets) would be included as an appendix. The data will include records of the quality and volume of waste waters generated and disposed of.

g. as built drawings will verify the extent of excavation and location of validation sampling points.

h. Photographic records showing placement of cover material in landscaping.

i. the results of all validation tests.

j. regulatory approval for gas mitigation design, records and photographs of installation, records of independent inspection by a qualified competent person, in accordance with CIRIA C735 (CIRIA, 2014) and BS 8485:2015+A1:2019 (British Standards Institution, 2019).

k. contact details for consultees, provide records of visits to site by regulators and details of planning conditions discharged during or prior to the works.

l. any changes made to the materials management plan, waste recovery plan, and deployment plan.

m. evidence of compliance with the materials management plan or waste recovery plan.

8.9.3 If necessary, the verification report must be submitted to the local planning authority and the Environment Agency for written acceptance.

8.10 Post Construction Management Plan

8.10.1 On the completion of the works, a post-construction management plan must be maintained as part of the Health and Safety file for the site. This should include:

a. Management of the risks from contaminated ground (e.g., asbestos fibres, ground gases and vapours during below ground maintenance work or work in retained in landscaping).

b. General personal protective equipment and control measures required for maintenance work involving the handling of made ground and organic soils.

c. Areas of restricted access and measures for working in these areas.

d. Establishment of a programme of safety checks for workers entering confined spaces in areas of made ground, deep fill, or organic soils with an increased risk of ground gas and/or vapour to be present.

8.10.2 It should be noted that there is potential for contamination to remain on-site post remediation, and this may require additional control measures to be included as part of the post-construction management plan.

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Glossary

Term	Abbreviation	Explanation
Annual Average	**AA**	N/A
Above ordnance datum	**AOD**	Above ordnance datum, vertical datum used by an ordnance survey as the basis for delivering altitudes on maps.
AGS data format		Data in AGS format (.ags) is a text file format used to transfer data reliably, between organisations in the site investigation industry, independent of software, hardware or operating system.
Annual Average		Annual average (AA). Concentration or parameter value average over 12 months and based on a minimum of 12 individual sample results.
Anthropogenic		Created by people or caused by human activity.
Area of Outstanding Natural Beauty	**AONB**	Statutory designation intended to conserve and enhance the ecology, natural heritage and landscape value of an area of countryside.
Aquifers – Principal		These are layers of rock or drift deposits that have high intergranular and/or fracture permeability – meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.
Aquifers – Secondary A		Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.
Aquifers – Secondary B		Mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers.
Aquifers – Secondary undifferentiated		Secondary undifferentiated are aquifers where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value.
Asbestos Containing Material	**ACM**	Any material containing more than one percent asbestos. These materials are considered hazardous and associated with certain diseases and health concerns
Association of Geotechnical and Geo-Environmental Specialists	**AGS**	A not-for-profit trade association established to improve the profile and quality of geotechnical and geoenvironmental engineering. The membership comprises UK organisations and individuals having a common interest in the business of site investigation, geotechnics, geoenvironmental engineering, engineering geology, geochemistry, hydrogeology, and other related disciplines.
Benzene, toluene, ethylbenzene and xylenes	**BTEX**	A group of volatile organic compounds, comprising benzene, toluene, ethylbenzene and xylene
Biological Oxygen Demand	**BOD**	The amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present

Term	Abbreviation	Explanation
		in a given water sample at certain temperature over a specific time period.
Borehole	**BH**	A hole bored into the ground, usually as part of investigations, typically to test the depth and quality of soil, rock and groundwater. A borehole can also be used to dewater the ground.
British Geological Survey	**BGS**	A partly publicly funded body which aims to advance geoscientific knowledge of the United Kingdom landmass and its continental shelf by means of systematic surveying, monitoring and research.
British Standard	**BS**	Standards produced by the British Standards Institution, which is incorporated under royal charter and formally designated as the national standards body for the UK.
British Standards Institution	**BSI**	The national standards body of the UK, producing technical standards for various industries.
BritPits		An abbreviation of British Pits. The database holds information on: • names of mines, quarries, oil wells, gas wells, ash and desulphogypsum plants • geographic location • address • operator • mineral planning authorities • geology • mineral commodities produced • end-uses (where known)
C4SL		Category 4 Screening Levels for assessment of land affected by contamination as published by DEFRA in document SP1010, produced by CL:AIRE.
Chartered Institute of Environmental Health	**CIEH**	The Chartered Institute of Environmental Health (CIEH) is the membership and awarding body for the environmental health sector.
Chemical Oxygen Demand	**COD**	The amount of oxygen required to oxidise all soluble and insoluble organic compounds present in a volume of water
Combined sewer overflow	**CSO**	Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same system.
Conceptual site model	**CSM**	A land contamination CSM refers to the source-pathway-receptor (SPR) linkage approach for identifying pollutant linkages. Development and refinement of the CSM is part of the process defined in LCRM guidance.
Construction Environmental Management Plan	**CEMP**	The primary environmental management document that defines the procedures for achieving the objectives set out in the environmental policy. It incorporates environmental performance targets set for the Project.
Construction Industry Research	**CIRIA**	A not-for-profit, independent organisation that facilitates a range of collaborative activities to help improve the construction industry.

Term	Abbreviation	Explanation
Information Association		
Contaminant of Concern	**CoC**	N/a
Contaminated Land: Applications in Real Environments	**CL:AIRE**	independent not-for-profit organisation established to stimulate the regeneration of contaminated land in the UK.
Controlled Waters		Waters including groundwater, freshwater and saline water as defined in the UK Water Resources Act 1991.
Control of Major Accident Hazards	**COMAH**	The regulatory framework to prevent and mitigate the effects of major accidents involving dangerous substances which can cause serious damage/harm to people and/or the environment.
Department for Environment, Food and Rural Affairs	**Defra**	Department for Environment, Food and Rural Affairs: the government department responsible for environmental protection, food production and standards, agriculture, fisheries and rural communities in the United Kingdom of Great Britain and Northern Ireland.
Deneholes		An underground structure consisting of a number of small chalk caves entered by a vertical shaft.
Detailed Quantitative Risk Assessment	**DQRA**	Tier 3 of the risk assessment process according to LCRM guidance on the assessment of land contamination. A DQRA uses detailed site-specific information to estimate risk.
Dichlorodiphenyltrichloroethane	**DDT**	A synthetic organic compound used as an insecticide.
Digital Terrain Model	**DTM**	A bare-earth model that contains elevations of natural terrain features such as ridge tops and river valleys. Elevations of vegetation and features, such as buildings and roads, are digitally removed.
Drinking Water Standards	**DWS**	Concentrations of substances or other parameter values and properties define by regulation or guidance, below which water is considered 'wholesome' and fit for potable use. In the UK, DWS are defined by the Water Supply (Water Quality) Regulations 2016
Duplicate sample		A sample taken for quality assurance purposes. A duplicate sample is a sample which is obtained from the same location and depth, at the same time and on the same day, and via the same sampling method as the original or 'parent' sample.
ESdat		Specialist environmental database system; used to validate, import and analyse environmental data.
Environment Agency	**EA**	A non-departmental public body of Defra. The Environment Agency is the leading public body for protecting and improving the environment in England.
Environmental Impact Assessment	**EIA**	A process by which information about environmental effects of a proposed development is collected, assessed and used to inform decision making. For certain projects, EIA is a statutory requirement, reported in an Environmental Statement.

Term	Abbreviation	Explanation
Environmental Permitting (England and Wales) Regulations 2016 (as amended)	**EPR**	N/a
Environmental Quality Standards	**EQS**	Concentrations of substances or other parameter values and properties define by regulation or guidance for the protection of the environment.
Field Blank		A blank or 'clean' sample taken for quality assurance purposes and created in the field by the sampler.
Generic Assessment Criteria	**GAC**	Parameter values, such as substance concentrations, defined based on generic assumptions (i.e, non site-specific) for the quantitative assessment of risk. Concentrations below a GAC typically present a low or minimal risk to the receptor(s) which they are defined as protective of. Concentrations above a GAC do not necessarily represent a risk, but may indicate the need for action such as further assessment.
Generic Quantitative Risk Assessment	**GQRA**	Tier 2 of the risk assessment process according to LCRM guidance on the assessment of land contamination. A GQRA uses generic assessment criteria and assumptions to estimate risk.
Geographic information system	**GIS**	An integrated collection of computer software and data used to view and manage information about geographic places, analyse spatial relationships, and model spatial processes.
Grab sample	**GS**	Samples of any media are either involve grab sampling or composite sampling. Grab samples are collected at one location and at one point in time.
Ground investigation	**GI**	N/a
Heavy fuel oil	**HFO**	A residual fuel incurred during the distillation of crude oil.
Hectares	**Ha**	N/a
Historical Land Use Data	**HLUD**	A Landmark dataset
Historical Land Use	**HLU**	N/a
Historical Tanks and Energy Facilities	**HTEF**	A Landmark dataset
HoleBASE		Geotechnical data knowledge management system
Industrial, Commercial, Agricultural and Recreational	**ICAR**	A land use
Integrated Pollution Prevention and Control	**IPPC**	Refers to the minimising of pollution from various industrial sources throughout the European Union (EU), as established by the IPPC Directive (Directive 2008/1/EC of 15

Term	Abbreviation	Explanation
		January 2008 concerning integrated pollution prevention and control).
Interceptor		Part of a wastewater treatment system that collects substances such as silt, grit and soil, as well as traces of oil and fuel prior to discharge or further treatment.
Intermediate bulk container	**IBC**	Industrial-grade containers engineered for the mass handling, transport, and storage of liquids, semi-solids, pastes, or solids.
International Organization for Standardisation	**ISO**	An international standard setting organisation, composed of a network of national standards bodies.
Litres per hour	**l/h**	N/a
Land Contamination: Risk Management	**LCRM**	Formerly CLR11 Model Procedures for the Management of Land Contamination.
Light Detection and Ranging	**LiDAR**	A surveying method that measures distance to a target by illuminating that target with a laser light.
Light Non-Aqueous Phase Liquid	**LNAP**	A contaminant that is not soluble in water and has lower density than water.
Limits of deviation	**LOD**	The tolerances, both laterally and vertically, that any parts of the Project can be constructed from the lines and situations shown on the Works Plans (Application Document 2.6) and the levels shown on the Engineering Section Drawings (Application Document 2.9).
Liquified petroleum gas	**LPG**	A fuel gas which contains a flammable mixture of hydrocarbon gases, specifically propane and butane
Local Authority Pollution Prevention and Control	**LAPPC**	A system which applies an integrated environmental approach to regulate certain industrial activities.
Local geological sites	**LGS**	Locally non-statutory designated geological sites of local, national or regional importance.
Local nature reserve	**LNR**	Locally designated nature site protected through the planning system.
Local wildlife site	**LWS**	A non-statutory designation for sites with substantive nature conservation value.
Long term monitoring	**LTM**	N/a
LQM/CIEH Suitable for Use Levels		Human health generic assessment criteria produced by Land Quality Management and the Chartered Institute of Environmental Health.
Maximum allowable concentration	**MAC**	An EQS for a pollutant may either be an AA or a MAC. MAC are used to assess individual monitoring events from continuous or regular monitoring when the AA of the pollutant is below the AA EQS.
Made ground		Anthropogenic soils placed by man.

Term	Abbreviation	Explanation
Metal Bioavailability Assessment Tool		The toxicity of metals is dependent on a range of water quality parameters that influence the amount of dissolved metal that is bioavailable, i.e. responsible for toxic effects on aquatic plants and animal. The M-BAT tool allows the bioavailable concentration of metals dissolved in water to be calculated.
Method Detection Limit	**MDL**	Method Detection Limit
Methyl Tert-Butyl Ether	**MTBE**	An organic compound used as a fuel (petrol) additive.
Metres below datum	**Mbdat**	Vertical datum used by an ordnance survey as the basis for delivering altitudes on maps.
Metres below ground level	**M bgl**	N/a
Millibar	**Mbar**	N/a
Ministry of Housing, Communities and Local Government	**MHCLG**	Formed in January 2018, the MHCLG took over the duties of the former Department for Communities and Local Government. In September 2021, it was renamed the Department for Levelling Up, Housing and Communities.
National Grid Reference	**NGR**	A system of geographic grid references used in Great Britain to enable positional reference on the Ordnance Survey National Grid.
National Planning Policy Framework	**NPPF**	Published in March 2012 by the UK's Department of Communities and Local Government, consolidating over two dozen previously issued documents called Planning Policy Statements (PPS) and Planning Policy Guidance Notes (PPG) for use in England.
Nitrate vulnerable zone	**NVZ**	Areas covering 62% of England designated as a result of the European Union's Nitrates Directive in order to reduce the level of nitrates in surface and groundwater. Farmers with land in nitrate vulnerable zones have to follow mandatory rules to tackle nitrate loss from agriculture.
Notification of Installations Handling Hazardous Substances	**NIHHS**	
Ordnance datum	**OD**	A standardised point representing average (mean) sea level, used by the Ordnance Survey as the basis for measurement of height (altitude) on UK maps, reported as metres 'above ordnance datum'.
Ordnance Survey	**OS**	The national mapping agency of Great Britain.
Organo-phosphorus	**OP**	Organophosphorus compounds are organic compounds containing phosphorus. They are used primarily in pest control as an alternative to chlorinated hydrocarbons that persist in the environment.
Parts per million by volume	**ppmv**	n/a

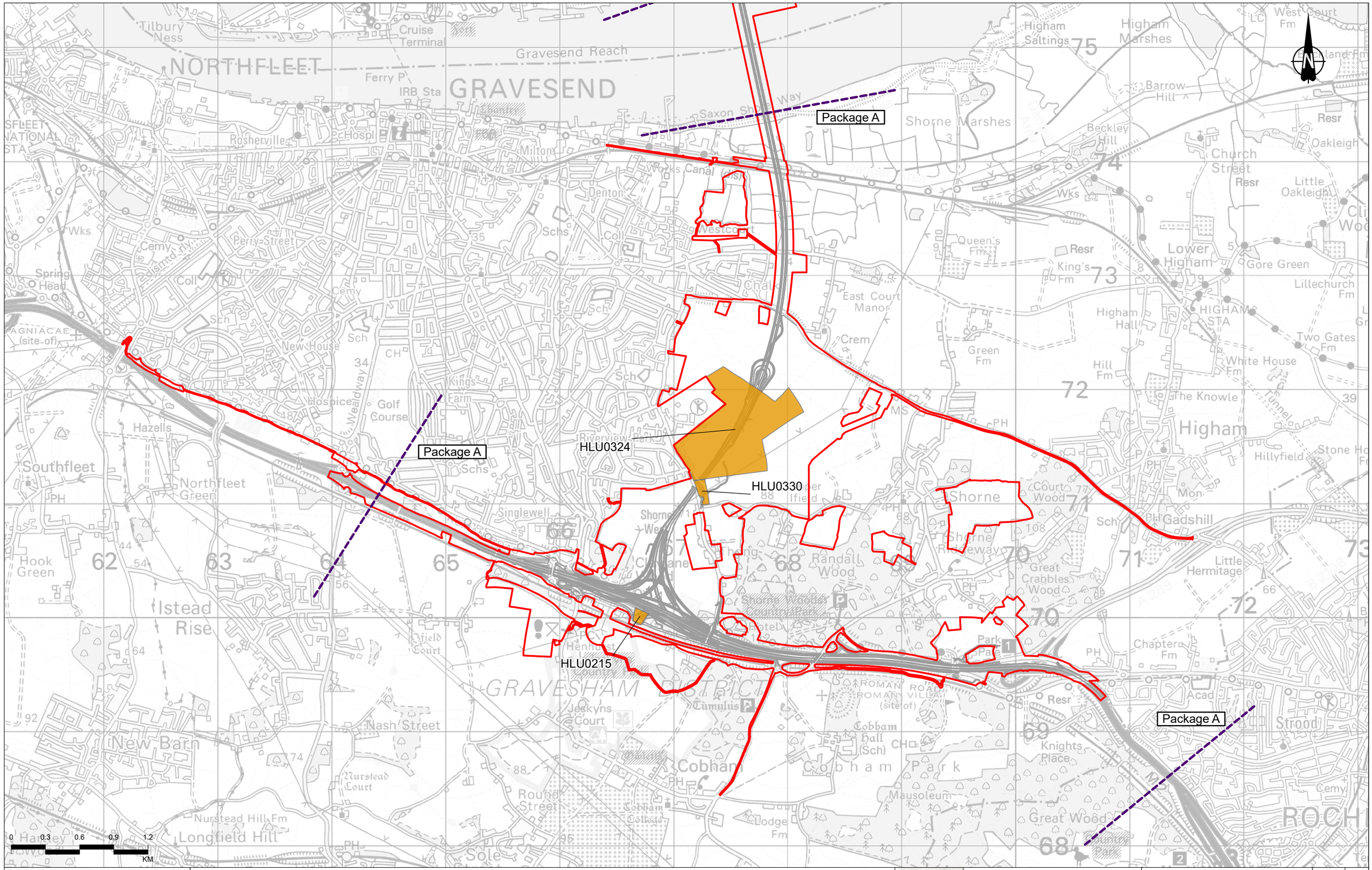
Term	Abbreviation	Explanation
Per-/Poly-Fluoroalkyl Substances	**PFAS**	A family of human-made chemicals found in a wide range of products used by consumers and industry. Many PFAS are resistant to grease, oil, water, and heat.
Perfluoro-octane-sulfonic acid	**PFOS**	A chemical compound having an eight-carbon fluorocarbon chain and a sulfonic acid functional group and thus a perfluorosulfonic acid. It is an anthropogenic fluorosurfactant, now regarded as a global pollutant.
Perfluorooctanoate	**PFOA**	A perfluorinated carboxylic acid produced and used worldwide as an industrial surfactant in chemical processes and as a material feedstock
Persistent Organic Pollutants	**POP**	N/a
Petrol filling station	**PFS**	N/a
Photo-Ionisation Detector	**PID**	A type of gas detector.
Pollutant linkage		A pollutant linkage comprises a source, pathway and receptor. A contaminant source, environmental and/or exposure pathway and sensitive receptor is a pollutant linkage which gives rise to a potential risk to the receptor.
Polychlorinated biphenyls	**PCBs**	A group of man-made compounds that were widely used in the past, mainly in electrical equipment, but which were banned at the end of the 1970s in many countries because of environmental concerns. Because these compounds are generally very stable, they remain present in the environment today.
Polycyclic aromatic hydrocarbons	**PAHs**	A group of several hundred chemically related, environmentally persistent, organic compounds of various structures and varied toxicity.
Port of London Authority	**PLA**	A self-funding public trust established by The Port of London Act 1908 to govern the Port of London. Its responsibility extends over the Tideway of the River Thames and its continuation (the Kent/Essex strait). It maintains and supervises navigation, and protects the river's environment.
Predicted No-Effect Concentrations	**PNEC**	the concentration of a chemical which marks the limit at which below no adverse effects of exposure in an ecosystem are measured.
Preliminary Environmental Information Report	**PEIR**	An early output of the EIA process, and part of the DCO application process.
Preliminary Risk Assessment	**PRA**	Tier 1 of the risk assessment process according to LCRM guidance on the assessment of land contamination. A PRA develops a conceptual site model.
Preliminary Sources Study Report	**PSSR**	N/a
Public Health England	**PHE**	PHE was an executive agency of the Department of Health and Social Care in the UK that began operating on 1 April 2013. PHE's mission was 'to protect and improve the nation's health and to address inequalities'. From 1 October 2021, PHE's health protection functions were formally

Term	Abbreviation	Explanation
		transferred into the UK Health Security Agency, while its health improvement functions were transferred to the Office for Health Improvement and Disparities, NHS England and NHS Digital.
Public open space	**PoS**	Land use
Pulverised Fuel Ash	**PFA**	Also referred to as fly ash, is the ash resulting from the burning of pulverised coal in coal-fired electricity power stations.
Qualitative Risk Assessment	**QRA**	Refinement of the CSM by reviewing qualitative and quantitative information sources.
Ramsar site		A wetland of international importance, designated under the Ramsar convention.
River Terrace Deposits	**RTD**	Sand and gravel, locally with lenses of silt, clay or peat.
Semi-volatile organic compounds	**SVOC**	Organic compounds that tend to have a higher molecular weight and higher boiling point temperature than VOCs.
Special Area of Conservation	**SAC**	Land designated under Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora. SACs protect habitats and species considered to be of European interest.
Special Protection Area	**SPA**	Land classified under Directive 79/409 on the Conservation of Wild Birds. SPAs protect rare and vulnerable birds and regularly occurring migratory species.
Site of Special Scientific Interest	**SSSI**	Land notified as an SSSI under the Wildlife and Countryside Act (1981), as amended. SSSI are the finest sites for wildlife and natural features in England, supporting many characteristic, rare and endangered species, habitats and natural features.
Source-Pathway-Receptor linkage	**SPR linkage**	The approached used to describe pollutant linkages where a source is a known or potential source of contamination and a receptor is an environmental, human or built receptor which may be caused harm. A pathway is the route linking a source and receptor by which exposure or harm occurs.
Source protection zone	**SPZ**	Part of a groundwater catchment used for public water supply. SPZ are designated by the Environment Agency for the protection of public water supply from contamination from potentially polluting activities and accidental releases of pollutants.
Superceptor		A brand model of interceptor. A Superceptor is full retention interceptor, meaning that all flow is treated, and oil or fuel retained. Designed for use in areas where there is the possibility of spillage of pollutants such as petrol filling stations where all of the discharge from the area must be intercepted.
Surface water	**SW**	N/a
sustainable drainage system	**SuDS**	A sustainable drainage system designed to reduce the potential impact of new and existing developments with respect to surface water drainage discharges.

Term	Abbreviation	Explanation
Synthetic Pyrethroid (pesticide)	**SP**	Lipophilic insecticides whose biological activity seems to be directly related to their chemical structure.
Tentatively Identified Compound	**TIC**	Non-target compound tentatively identified during analysis from a library of potential compounds. Reported concentration maybe semi-quantitative and unaccredited.
Total Organic Content	**TOC**	N/a
Total Petroleum Hydrocarbons	**TPHs**	A term used for any mixture of hydrocarbons that are found in crude oil.
Tributyltin	**TBT**	A toxic chemical used for various industrial purposes, including prevention of growth of marine organisms on the hulls of ships, disinfection of circulating industrial cooling waters, and the preservation of wood.
Trip blank		A clean sample of a matrix (eg water) is taken from the laboratory to the sampling site and transported back to the lab without having been exposed to the sampling procedure.
UK Drinking Water Standards	**UK DWS**	Standards for a wide range of substances, organisms and properties of water as set by the European Drinking Water Directive (98/83/EC) and national standards in order to protect public health.
UK Power Network	**UKPN**	An energy network operator. Owns and maintains the electricity cables in South East England, the East of England and London.
Unexploded bomb	**UXB**	See ‘unexploded ordnance’.
Unexploded ordnance	**UXO**	Explosive remnants of war that did not explode when they were deployed and may still pose a risk of detonation. Sometimes referred to as UXBs.
Unproductive strata		Rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.
Volatile organic compound	**VOC**	Organic compound that is volatile under normal environmental/atmospheric conditions, although it can be found in the ground in the solid, liquid and dissolved phase form as well as in gaseous phase
Water Framework Directive	**WFD**	A European Community Directive (2000/60/EC) of the European Parliament and council designed to integrate the way water bodies are managed across Europe.
volume per volume	**% v/v**	Volume concentration of a solution, expressed as % v/v, which stands for volume per volume
weight per weight	**% w/w**	Weight concentration of a solution, expressed as % w/w, which stands for weight per weight

Annexes

Annex A Figures



Legend

- Route alignment
- Order Limits
- Phase 2 Ground Investigation Packages boundaries

Medium and high-risk credible contaminant source:
Generic Quantitative Risk Assessment Rating
- Medium

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	04/10/2022	DCO Application	SW	BP	SH

Client: national highways

Project: LOWER THAMES CROSSING

Status	DCO APPLICATION
Original Size	A3
Revision	P01
Application Document Number	TR010032/APP/6.3
Scale	1:30,000

Drawing Title: Medium and high-risk credible contaminant sources

Drawing Number: HE540039-CJV-GEN-GEN-MAP-GEO-00222

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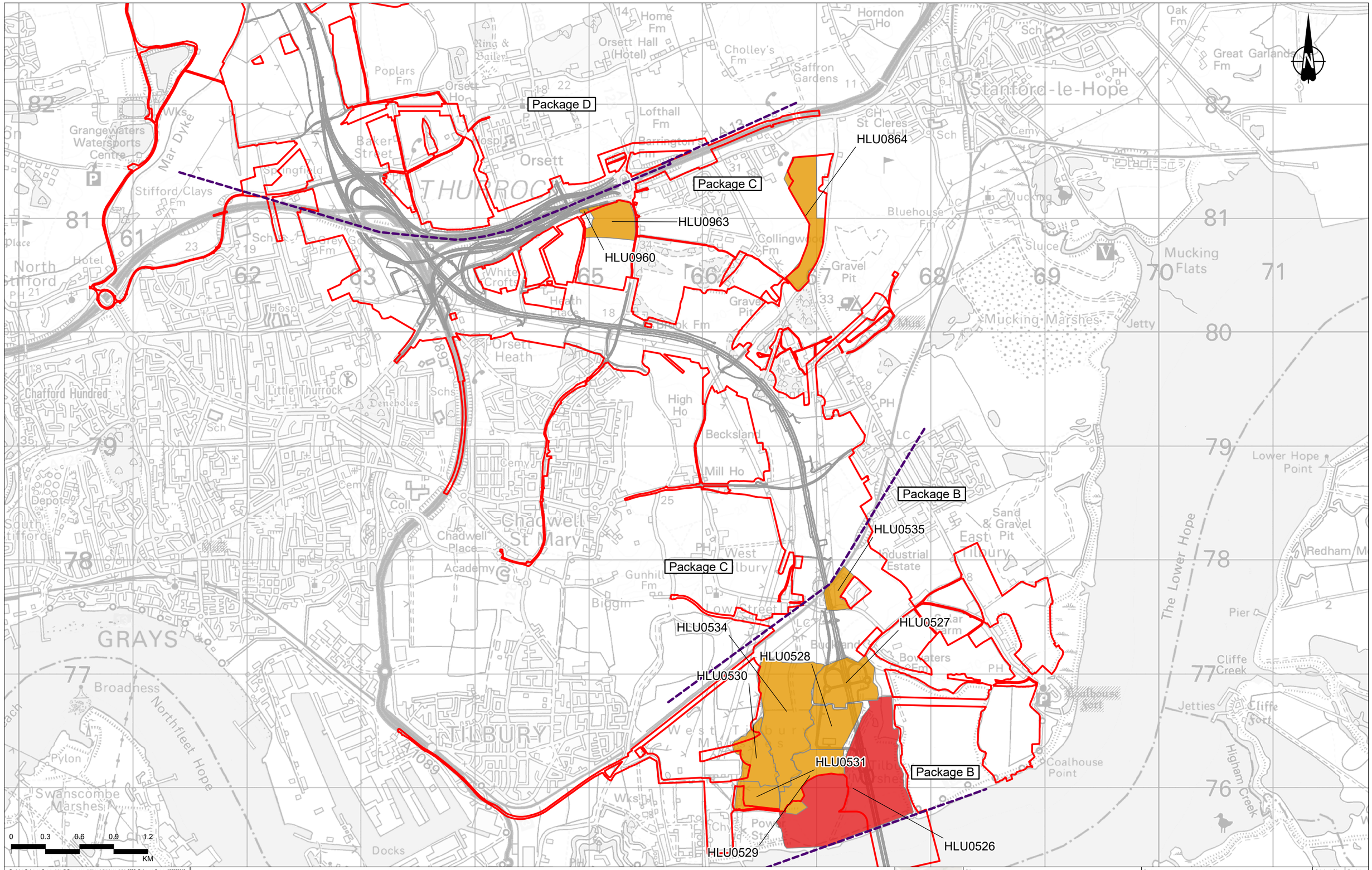

Legend

- Route alignment
- Order Limits
- Phase 2 Ground Investigation Packages boundaries

Medium and high-risk credible contaminant source:
Generic Quantitative Risk Assessment Rating

- High
- Medium

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	04/10/2022	DCO Application	SW	BP	SH

Client: national highways

Project: LOWER THAMES CROSSING

Status	DCO APPLICATION
Original Size	A3
Revision	P01
Application Document Number	TR010032/APP/6.3
Scale	1:30,000

Drawing Title: Medium and high-risk credible contaminant sources

Drawing Number: HE540039-CJV-GEN-GEN-MAP-GEO-00222

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Package D

HLU1151

Package D

HLU1062

0 0.3 0.6 0.9 1.2 KM

Legend

- Route alignment
- Order Limits
- Phase 2 Ground Investigation Packages boundaries

Medium and high-risk credible contaminant source:
Generic Quantitative Risk Assessment Rating
- Medium

Generic Quantitative Risk Assessment Rating
- Medium

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	04/10/2022	DCO Application	SW	BP	SH

Client: national highways

Project: LOWER THAMES CROSSING

Status	DCO APPLICATION
Original Size	A3
Revision	P01
Application Document Number	TR010032/APP/6.3
Scale	1:30,000

Drawing Title: Medium and high-risk credible contaminant sources

Drawing Number: HE540039-CJV-GEN-GEN-MAP-GEO-00222

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Annex B Feasible remediation options

Name	Ref. No	Description	Potential Contaminants	Potential Significance of Pollutant Linkage	Soil																										Comments
					In situ biological treatment			In situ physical or chemical treatment						In situ thermal treatment	Ex situ biological treatment (assuming excavation)				Ex situ physical or Chemical Treatment							Contain-ment	Other	Ex Situ Thermal Treatment (assuming excavation)				
					Bioventing	Enhanced bioremediation	Phytoremediation	Chemical oxidation	Electro kinetic separation	Soil flushing	Soil vapour extraction	Solidification/stabilisation	Thermal treatment (with or without SVE)	Biopiles and Windrows	Landfarming	Slurry phase biological treatment	Chemical extraction	Chemical reduction or oxidation	Dehalogenation	Separation	Soil washing	Solidification and stabilisation	Capping Layer or Cover System	Excavation and Disposal	Incineration	Pyrolysis	Thermal desorption	
Esso A2 Westbound Petrol Filling Station	**HLU0215**	Vehicle garage and petrol filling station (1972-present). Possible Made Ground to west.	Petroleum hydrocarbons, PAH, methyl tert-butyl ether (MTBE), metals, inorganics, VOC, SVOC, asbestos, hazardous gases.	Operational PFS. Known (minor) hydrocarbon impacts to soil. Site redeveloped in 2010 and environmental condition reports available.	■	■			■	■	■	■		■	■	■	■	■			■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Southern Valley Golf Course	**HLU0324**	Golf course (1998 to present).	Metals, petroleum hydrocarbons, PAH, asbestos, herbicides, pesticides. Results of the ground investigation have indicated the presence of potential lead, PAH, and asbestos soil contamination	Potential for deleterious materials in imported fill and bulk storage of fuel and pesticides. Rating increased due to the potential size of affected area.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options
Goshems Farm Landfill	**HLU0526**	Former early 20th century landfill, reportedly mostly ash and bottles, dock and river dredgings. Currently undergoing restoration.	Metals, inorganics, petroleum hydrocarbons, PAH, PFAS, ammoniacal nitrogen, asbestos, tributyltin (TBT), SVOC, VOC, hazardous gases. Results of the ground investigation have indicated the presence of potential heavy metal, asbestos, and PAH soil contamination	Potential for wide range of contaminants to be present in area of north portal excavation. Adjacent to surface water and within SPZIII. Potential for ground gas generation from organic wastes (dredgings) and natural alluvium. Location near north portal increases the potential for adverse effect on the route.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal. Asbestos either addressed by pathway management (cover system) or removal. Limited techniques available to destroy PFAS.
Tilbury Ash Disposal Site - Area C2	**HLU0527**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Tilbury Ash Disposal Site - Area C	**HLU0528**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Tilbury Ash Disposal Site - Area B	**HLU0529**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Tilbury Ash Disposal Site - Area A3	**HLU0530**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal. Location near north portal increases the potential for adverse						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Tilbury Ash Disposal Site - Area A2	**HLU0531**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal. Location near north portal increases the potential for adverse						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Tilbury Ash Disposal Site - Area A1	**HLU0532**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal. Location near north portal increases the potential for adverse effect on the route.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Tilbury Ash Disposal Site - Shed Marsh Landfill	**HLU0534**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Low Street Landfill	**HLU0535**	Industrial/ commercial landfill (1969 to 1976).	Metals, inorganics, petroleum hydrocarbons, PAH, PFAS, phenols, ammoniacal nitrogen, asbestos, hazardous gases, VOC, SVOC. Results of the ground investigation identified discrete asbestos soil contamination in the made ground	Potential for wide range of contaminants to be present in the area to the east of the Tilbury Junction excavation. Potential for ground gas generation from organic wastes (dredgings) and natural alluvium. Location near north portal increases the potential						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal. Limited techniques available to destroy PFAS.
Welcome Villa PFS	**HLU0960**	Former PFS (approximately 1960 onwards), now residential property. Tanks may still be present.	Petroleum hydrocarbons, MBTE, BTEX, metals, inorganics, asbestos, VOC, SVOC, hazardous gases.	Relatively small compared to other PFS identified. Although tanks may still be present, given age and size, primary sources are unlikely large enough to justify a severe rating although along route alignment. Potential impacts to soils and groundwater from historic material storage and spills. Potential for unrecorded pollution incidents.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal.
Ockendon Grays Areas II & III Landfill	**HLU1062**	Active Veolia non-hazardous and inert landfill. Filled 1974 to present.	Metals, inorganics, organics, petroleum hydrocarbons, PAH, PFAS, ammoniacal nitrogen, asbestos, hazardous gases, VOC, SVOC.	Recently operational and permitted landfill. Cells are likely to be outside of route alignment. May influence baseline soil and groundwater quality due to size of landfill.						■	■	■		■	■	■					■	■			■			■		■	Metals and organics require separate treatment options. Asbestos either addressed by pathway management (cover system) or removal. Limited techniques available to destroy PFAS.
Asbestos containing irrigation pipes, Hall Farm.	**HLU1151**	Subsurface irrigation pipes reported to contain asbestos.	Asbestos.	Likely to require removal by specialist contractor due to pipes located beneath route.																									Asbestos either addressed by pathway management (cover system) or removal.

Notes

■ Potentially suitable for some of CoC identified, dependent on CSM - above average suitability

■ Potentially suitable for some of CoC identified, dependent on CSM - average suitability

Unlikely suitable for CoC identified

Site Details						Water																											
Section	Name	Ref. No	Description	Potential Contaminants	Potential Significance of Pollutant Linkage	In situ biological			In situ physical/chemical								Ex situ biological		Ex situ physical/chemical											Contain-ment	Comments
						Enhanced bioremediation and enhanced natural attenuation	Monitored natural attenuation	Phytoremediation	Air sparging and biosparing	Vacuum enchanced recovery and Bioslurping	Chemical oxidation	Dual phase extraction	Thermal treatment	In-well air stripping	Passive or Reactive Treatment walls		Bioreactors	Constructed wetlands	Adsorption and Absorption	Advanced oxidation and electrochemical	Air stripping	Granulated activated carbon and liquid phase carbon adsorption	Groundwater containment and treat, and Soil Vapour Extraction	Ion exchange	Precipitation, Coagulation and Flocculation	Separation	Physical barriers	
A2 West	Esso A2 Westbound Petrol Filling Station	**HLU0215**	Vehicle garage and petrol filing station (1972-present). Possible Made Ground to west.	Petroleum hydrocarbons, PAH, methyl tert-butyl ether (MTBE), metals, inorganics, VOC, SVOC, asbestos, hazardous gases.	Operational PFS. Known (minor) hydrocarbon impacts to soil. Site redeveloped in 2010 and environmental condition reports available.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
A226	Southern Valley Golf Course	**HLU0324**	Golf course (1998 to present).	Metals, petroleum hydrocarbons, PAH, asbestos, herbicides, pesticides.	Potential for deleterious materials in imported fill and bulk storage of fuel and pesticides. Rating increased due to the potential size of affected area.																								Metals and organics require separate treatment options
	Nursey	**HLU0330**	Plant nursery, approximately 1955 to present. Significant waste storage.	Petroleum hydrocarbons, PAH, metals, inorganic, herbicides, pesticides, asbestos	Potential impact to soil due to unrecorded releases or uncontrolled waste disposal, unlikely significant risk due to likely localised impact.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Goshems Farm Landfill	**HLU0526**	Former early 20th century landfill, reportedly mostly ash and bottles, dock and river dredgings. Currently undergoing restoration.	Metals, inorganics, petroleum hydrocarbons, PAH, PFAS, ammoniacal nitrogen, asbestos, tributyltin (TBT), SVOC, VOC, hazardous gases.	Potential for wide range of contaminants to be present in area of north portal excavation. Adjacent to surface water and within SPZIII. Potential for ground gas generation from organic wastes (dredgings) and natural alluvium. Location near north portal increases the potential for adverse effect on the route.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater. Limited techniques available to destroy PFAS.
Thames North	Tilbury Ash Disposal Site - Area C2	**HLU0527**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Tilbury Ash Disposal Site - Area C	**HLU0528**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Tilbury Ash Disposal Site - Area B	**HLU0529**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Tilbury Ash Disposal Site - Area A3	**HLU0530**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal. Location near north portal increases the potential for adverse																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Tilbury Ash Disposal Site - Area A2	**HLU0531**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal. Location near north portal increases the potential for adverse																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Tilbury Ash Disposal Site - Area A1	**HLU0532**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal. Location near north portal increases the potential for adverse effect on the route.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Tilbury Ash Disposal Site - Shed Marsh Landfill	**HLU0534**	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Metals, inorganics, petroleum hydrocarbons, PAH, ammoniacal nitrogen, asbestos, SVOC, VOC, hazardous gases.	Potential for a wide range of contaminants to be present but likely dominated by those associated with PFA. Potential impacts to groundwater and surface waters in the area of the north portal.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
Thames North	Low Street Landfill	**HLU0535**	Industrial/ commercial landfill (1969 to 1976).	Metals, inorganics, petroleum hydrocarbons, PAH, PFAS, phenols, ammoniacal nitrogen, asbestos, hazardous gases, VOC, SVOC.	Potential for wide range of contaminants to be present in the area to the east of the Tilbury Junction excavation. Potential for ground gas generation from organic wastes (dredgings) and natural alluvium. Location near north portal increases the potential																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater. Limited techniques available to destroy PFAS.
	Buckingham Hill Landfill	**HLU0864**	Former sand and gravel pit infilled with household waste from approximately 1967 to 1990. Maximum waste depth reported as 15m. (Thurrock Council, 2020) Current household waste and recycling centre to east. Still operational.	Metals, inorganics, petroleum hydrocarbons, PAH, PFAS, phenols, ammoniacal nitrogen, asbestos, hazardous gases, VOC, SVOC.	Records indicate site was restored with a capping layer but this is not confirmed. Possible groundwater impacts. Desk-based information and the results and assesement of gas monitoring undertaken adjacent to the landfill relating to areas of crop growth impacted by landfill gas																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater. Limited techniques available to destroy PFAS.
A13	Welcome Villa PFS	**HLU0960**	Former PFS (approximately 1960 onwards), now residential property. Tanks may still be present.	Petroleum hydrocarbons, MtBE, BTEX, metals, inorganics, asbestos, VOC, SVOC, hazardous gases.	Relatively small compared to other PFS identified. Although tanks may still be present, given age and size, primary sources are unlikely large enough to justify a severe rating although along route alignment. Potential impacts to soils and groundwater from historic material storage and spills. Potential for unrecorded pollution incidents.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater.
	Dansand Quarry	**HLU0963**	Aggregate recyclers and building material processing. Made Ground. Two recorded pollution incidents.	Petroleum hydrocarbons, PAH, metals, inorganics, asbestos.	Unlikely to be a significant risk. Quarry is located next to the existing A13.																								Metals and organics require separate treatment options
M25 Junction	Ockendon Grays Areas II & III Landfill	**HLU1062**	Active Veolia non-hazardous and inert landfill. Filled 1974 to present.	Metals, inorganics, organics, petroleum hydrocarbons, PAH, PFAS, ammoniacal nitrogen, asbestos, hazardous gases, VOC, SVOC.	Recently operational and permitted landfill. Cells are likely to be outside of route alignment. May influence baseline soil and groundwater quality due to size of landfill.																								Metals and organics require separate treatment options. Asbestos not mobile in groundwater. Limited techniques available to destroy PFAS.
M25 Junction	Asbestos containing irrigation pipes, Hall Farm.	**HLU1151**	Subsurface irrigation pipes reported to contain asbestos.	Asbestos.	Likely to require removal by specialist contractor due to pipes located beneath route.																								Asbestos not mobile in groundwater

Notes

Potentially suitable for some of CoC identified, dependent on CSM - above average suitability

Potentially suitable for some of CoC identified, dependent on CSM - average suitability

Unlikely suitable for CoC identified

Annex C Option appraisal of shortlisted remediation options

Technology	Stabilisation / Solidification	Containment with capping layer to break source pathway receptor linkage	Excavation & off site disposal / treatment			
Technical parameters				**Score**	**Weighted coefficient**	
Contaminant properties	**9** Proven technology used widely to treat CoC - contaminants are not degraded or broken down but locked up to prevent contact or exposure	**9** SPR linkage breakage would address primary remediation drivers associated with Human Health exceedances	**9** Proven technology used widely to treat CoC	0 - Technology not suitable 1 - Technology may work (50%) 2 - Technology will probably work (70%) 3 - Technology very suitable (90% +)	**x 3**	1 - Less Important 2 - Important **3 - Very Important**
Extent of contamination (concentration, distribution and plume dimensions)	**9** Technology can be applied to large treatment zones of highly contaminated materials	**9** Technology can be applied over large treatment zones	**9** Off Site Treatment Facilities routinely accept waste types	0 - Technology not suitable 1 - Technology may work (50%) 2 - Technology will probably work (70%) 3 - Technology very suitable (90% +)	**x 3**	1 - Less Important 2 - Important **3 - Very Important**
Geology / Hydrogeology suitable	**6** Made ground materials would require physical screening and crushing to facilitate treatment if Ex-situ treatment required	**9** No processing of materials required	**9** No processing of materials required	0 -Technology not suitable 1 - Technology may work (50%) 2 - Technology will probably work (70%) 3 - Technology very suitable (90% +)	**x 3**	1 - Less Important 2 - Important **3 - Very Important**
Technical score	**24**	**27**	**27**			
Technical ranking	**3**	**1**	**1**			
Operational parameters				**Score**	**Weighted coefficient**	
Operational implementation	**4** Access to all contaminated materials may not be possible due to potential site utilities remaining in situ. Excavation area closed off and increase traffic movements during excavation works	**6** Technology requires capping layer to be installed over treatment area	**4** Access to all contaminated materials may not be possible due to potential site utilities remaining in situ. Excavation area closed off and increase traffic movements during excavation works including off site.	0 - Impacts on site operation not acceptable 1 - High impact on working operation of site 2 - Minor impacts on working operation of site 3 - Minimal impacts on working operation of site	**x 2**	**1 - Less Important** 2 - Important 3 - Very Important

Technology	Stabilisation / Solidification	Containment with capping layer to break source pathway receptor linkage	Excavation & off site disposal / treatment			
Long term operational demands	**9** Post remediation groundwater monitoring anticipated.	**6** May cause some restrictions on future land development to avoid damage to the capping material or require cap to be reinstated if damaged	**9** Post remediation groundwater monitoring anticipated.	0 - Impacts on site operation not acceptable 1 - High impact on working operation of site 2 - Minor impacts on working operation of site 3 - Minimal impacts on working operation of site	**x 3**	1 - Less Important 2 - Important **3 - Very Important**
Operational requirements	**6** Treatment area would need to be cleared (above and below ground) prior to implementation, plant required for excavation during works additional areas required for implementing ex situ treatment.	**9** Technology only requires monitoring wells as remediation infrastructure	**6** Treatment area would need to be cleared (above and below ground) prior to implementation, plant required for excavation and disposal during works additional areas required for implementing ex situ treatment.	1 - Substantial operational requirement (e.g. power and large plant required) 2 - Relatively large operational requirement (e.g. power and portable plant) 3 - Very minor operational requirement (e.g. monitoring only)	**x 3**	1 - Less Important 2 - Important **3 - Very Important**
Health & safety / Nuisance	**3** Use of reagents and process plants to undertake soil treatment requires specialist H&S planning.	**9** Excavation and placement of shallow engineered material required	**3** Dust, noise, traffic and other nuisance would need to be managed. Significant increased traffic on wider site.	1 - Higher risk remediation activity / Higher potential for nuisance 2 - Lower risk remediation activity / lower potential for nuisance 3 - Minimal risk remediation activity / Minimal potential for nuisance	**x 3**	1 - Less Important **2 - Important** 3 - Very Important
Track record / Development status	**4** Limited application of this technology , trials recommended to confirm design.	**6** Commonly applied and proven technology	**6** Commonly applied and proven technology	1 - Remediation approach has had limited application at full scale 2 - Remediation approach been applied with successful case studies 3 - Remediation approach has been used extensively	**x 2**	1 - Less Important **2 - Important** 3 - Very Important
Operational Score	**26**	**36**	**28**			
Operational Ranking	**3**	**1**	**2**			

Technology	Stabilisation / Solidification	Containment with capping layer to break source pathway receptor linkage	Excavation & off site disposal / treatment			
Commercial parameters				**Score**	**Weighted coefficient**	
Residual liability	**3** Mass is not depleted, pathways to receptors on and off site need to be demonstrated to be controlled / broken.	**3** Mass is not depleted, pathways to receptors on and off site need to be demonstrated to be controlled / broken.	**6** Removal of contaminant mass from site	0 - Technology as stand alone not suitable to achieve remediation objective 1 - Technology may achieve remediation objective (50% possibility) 2 - Technology would achieve remediation objective (70% possibility) 3 - Technology would achieve remediation objective (90% possibility)	**x 3**	1 - Less Important 2 - Important **3 - Very Important**
Commercial availability	**2** Specialist equipment / reagents would be required	**3** Equipment required is readily available	**3** Equipment required is readily available	1 - Equipment not readily available 2 - Equipment available 3 - Equipment readily available	**x 1**	**1 - Less Important** 2 - Important 3 - Very Important
Implementation timescale	**3** Technology could be applied reasonably quickly	**3** Technology could be applied reasonably quickly	**3** Technology could be applied reasonably quickly	1 - Slow >3 years 2 - Moderate 1-3 years 3 - Fast <1 year	**x 1**	**1 - Less Important** 2 - Important 3 - Very Important
Remediation timescale	**3** Technology could be applied reasonably quickly	**3** Technology could be applied reasonably quickly	**3** Technology could be applied reasonably quickly	1 - Slow >10 years 2 - Moderate 5-10 years 3 - Fast <5 years	**x 1**	**1 - Less Important** 2 - Important 3 - Very Important
Capital cost	**6** Costs to be incurred in setting up and using specialist plant and treating with chemical reagents.	**9** Application of clean cap is relatively inexpensive	**6** Cost of disposal is potentially high, although excess materials in cuttings would require removal as part of project	1 - High 2 - Medium 3 - Low	**x 3**	1- Less Important 2 - Important **3- Very Important**
Sustainability	**6** Treatment of soils using medium energy intensive technology	**9** Reuse of suitable site won materials under MMP	**3** Large volume to landfill unsustainable solution, high carbon footprint including haulage	1 - Low 2 - Medium 3 - High	**x 3**	
Operation & maintenance cost	**3** Enabling works, excavation safety controls, some dewatering and nuisance controls required as well as large plant. May require long-term maintenance of protection systems and/or long-term monitoring	**9** Integrity of capping layer can be maintained under general highways landscape maintenance programme	**3** Enabling works, excavation safety controls, some dewatering and nuisance controls required as well as large plant and backfill material during active works	1 - High 2 - Medium 3 - Low	**x 3**	1 - Less Important 2 - Important **3 - Very Important**

Technology	Stabilisation / Solidification	Containment with capping layer to break source pathway receptor linkage	Excavation & off site disposal / treatment	
Commercial score	20	36	27	
Commercial ranking	3	1	2	
Overall summary				
Overall score	70	99	82	
Overall ranking	3	1	2	

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