A417 Missing Link
TR010056

6.2 Environmental Statement
Chapter 9 Geology and Soils

Planning Act 2008

APFP Regulation 5(2)(a)
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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A417 Missing Link

Development Consent Order 202[x]

6.2 Environmental Statement
Chapter 9 Geology and Soils

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9.1 Introduction

9.1.1 This chapter reports the potential effects from the construction and operation of the proposed A417 Missing Link (the scheme, as detailed in ES Chapter 2 The project (Document Reference 6.2)) on geology and soils following the methodology set out in Design Manual for Roads and Bridges (*DMRB*) *LA 109 Geology and soils*[1].

9.1.2 This chapter details the methodology followed for the assessment, summarises the regulatory and policy framework related to geology and soils, and describes the existing environment in the area surrounding the scheme. Following this, the mitigation and residual effects of the scheme are discussed, along with the limitations of the assessment.

9.1.3 The existing environment in the area surrounding the scheme is considered with regard to:

- Bedrock geology and superficial deposits (including geological designations and sensitive/valuable non-designated features).
- Soil resources.
- Effects of potential land contamination on human health, surface water and groundwater.

9.1.4 This chapter sets out a baseline conceptual site model with respect to soil and groundwater contamination and identifies plausible contaminant linkages formed due to the construction or operational phases of the scheme.

9.1.5 The effects on geomorphology, associated with landforms, are described in ES Chapter 7 Landscape and visual effects (Document Reference 6.2). Effects on geomorphology, associated with hydromorphology, are described in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). Effects on archaeological artefacts are considered in ES Chapter 6 Cultural heritage (Document Reference 6.2).

9.1.6 The effects on mineral deposits as a resource and the suitability for reuse of soils are described in ES Chapter 10 Material assets and waste (Document Reference 6.2).

9.1.7 The effects on agricultural land holdings and development land and businesses are described in ES Chapter 12 Population and human health (Document Reference 6.2).

9.1.8 This chapter describes the potential effects of land contamination on groundwater and surface water quality. The potential effects on groundwater, hydrogeology and surface water as a result of drainage and discharge associated with the construction and operation of the scheme are considered in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

9.2 Competent expert advice

9.2.1 The geology and soils lead is a Chartered Geologist and Fellow of the Geological Society of London. They have a MESci (Hons) degree in Geology and MSc in Applied Environmental Geology, both from Cardiff University.

9.2.2 The geology and soils reviewer is a Chartered Engineer and a Member of the Institution of Civil Engineers. They are the Designer's Geotechnical Advisor for the scheme. They have a BSc (hons) in Geology from Cardiff University and an MSc in Engineering Geology (with distinction) from the University of Leeds.

9.2.3 The geology and soils chapter co-author is a Chartered Engineer and Member of the Institution of Civil Engineers. They have a MEng (Hons) degree in Environmental Engineering from the Wrocław University of Technology, Poland, and BSc (Hons) degree in Applied Sciences from the University of Glamorgan, Wales.

9.2.4 Full details for both are provided in ES Appendix 1.2 Competent expert evidence (Document Reference 6.4).

9.3 Legislative and policy framework

9.3.1 The following sub-sections present the wider legislation and policy relevant to the assessment of geology and soils.

Legislation

Geology

9.3.2 Geological sites of national importance are principally afforded protection under the Wildlife and Countryside Act 1981 or the *National Parks and Access to the Countryside Act 1949* by designation as a Site of Special Scientific Interest (SSSI) or National Nature Reserve (NNR). In addition, the Joint Nature Conservation Committee (JNCC) have carried out a *Geological Conservation Review* (GCR) and *Earth Science Conservation Review* (ESCR) to identify the best and most representative earth science sites in Great Britain, with a view to their long-term conservation. Although GCR/ESCR identification does not itself give any statutory protection, many GCR/ESCR sites have been notified as SSSIs.

Contaminated land

9.3.3 Environmental legislation and regulation provide separate drivers to manage contaminated land. The main legislative drivers for managing risks to human health and the environment from land contamination are:

- Part 2A of the Environmental Protection Act 1990 (the Contaminated Land Regime).
- The Contaminated Land (England) Regulations (2006).
- The Environment Act 1995.
- The Environmental Permitting (England and Wales) Regulations 2016.

9.3.4 Under Part 2A of the Environmental Protection Act 1990, sites are identified as 'contaminated land' if they are causing, or if there is a significant possibility of causing significant harm to human health or significant pollution of controlled waters, as defined by Section 104 of the Water Resources Act 1991. In general terms, the legislation advocates the use of a risk assessment approach for the assessment of contamination and remedial requirements.

9.3.5 The Environment (Amendment etc.) (EU Exit) Regulations 2019 came into force in accordance with the European Union (Withdrawal) Act 2018 on 31st December 2020. Part 2 amends the following primary legislation relevant to this chapter:

- The Environmental Protection Act 1990.
- The Environment Act 1995.

9.3.6 Part 3 of the Environment (Amendment etc.) (EU Exit) Regulations 2019 amends The Contaminated Land (England) Regulations 2006.

9.3.7 The amendments in these regulations make no changes to policy and the instruments will continue to operate substantively as they did prior to 31 December 2020.

9.3.8 Additional key legislation considered relevant to the assessment for geology and soils relating to contamination include:

- The Water Resources Act 1991.
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017.
- Department for Environment Food and Rural Affairs (Defra)The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.
- The Environmental Damage (Prevention and Remediation) Regulations 2009.

National and regional policy

9.3.9 As discussed in ES Chapter 1 Introduction (Document Reference 6.2), the primary basis for deciding whether or not to grant a Development Consent Order (DCO) is the *National Policy Statement for National Networks* (NPSNN), which sets out policies to guide how DCO applications will be decided and how the effects of national networks infrastructure should be considered. Table 9-1 identifies the NPSNN policies relevant to geology and soils, and then specifies where in this ES chapter information is provided to address the policy.

Table 9-1 Relevant NPSNN policies for geology and soils assessment

Relevant NPSNN paragraph reference	Requirement of the NPSNN	Where in this chapter is information provided to address this policy
5.23	*"The applicant should show how the project has taken advantage of opportunities to conserve and enhance (…) geological conservation interests."*	Section 9.9 Design, mitigation and enhancement measures outlines mitigation measures to conserve and enhance the geological interest at Crickley Hill and Barrow Wake Special site of Scientific Interest (SSSI). Section 9.10 Assessment of likely significant effects includes a detailed assessment of the impacts on existing geological exposures at Crickley Hill from construction and operation of the scheme.
5.168	*"Applicants should take into account the economic and other benefits of the best and most versatile agricultural land (defined as land in grades 1, 2 and 3a of the Agricultural Land Classification). Where significant development of agricultural land is*	Section 9.7 Baseline conditions identifies the Agricultural Land Classification (ALC) for land affected by the scheme. Current and historical sources of land contamination within the study area are also identified in this section and detailed in ES Appendix 9.2 Preliminary

Relevant NPSNN paragraph reference	Requirement of the NPSNN	Where in this chapter is information provided to address this policy
	demonstrated to be necessary, applicants should seek to use areas of poorer quality land in preference to that of a higher quality. Applicants should also identify any effects, and seek to minimise impacts, on soil quality, taking into account any mitigation measures proposed. Where possible, developments should be on previously developed (brownfield) sites provided that it is not of high environmental value. For developments on previously developed land, applicants should ensure that they have considered the risk posed by land contamination and how it is proposed to address this."	ground investigation report (Document Reference 6.4). Section 9.8 Potential impacts considers the potential impacts on agricultural land and the potential pollutant linkages during construction and operation of the scheme without mitigation. Section 9.9 Design, mitigation and enhancement measures sets out headline actions, principles and mitigation in relation to prevention and control of contamination and how effects on soil resources would be mitigated. These are presented in the Environmental Management Plan (EMP) (ES Appendix 2.1 Environmental Management Plan (Document Reference 6.4)). Section 9.10 Assessment of likely significant effects assesses the impacts on best and most versatile (BMV) agricultural land and contamination risks during construction and operation of the scheme.

9.3.10 In addition to the NPSNN, this chapter also considers the *National Planning Policy Framework* (NPPF)[2] and relevant Planning Practice Guidance[3], which emphasises the need for sustainable development in terms of the resources used, the maintenance of the environment, the economic use of land and consideration of society in the general area. The importance for the restoration of derelict and contaminated land is stated.

9.3.11 In relation to conserving and enhancing the natural environment, the NPPF states that impacts on geodiversity should be reduced by preventing harm to geological conservation interests. In the UK, geological sites are afforded consideration at a local level by designation, including:

- GCR sites (England, Scotland, Wales).
- Geoparks.
- Regionally Important Geological and Geomorphological Sites (RIGS).
- Locally Important Geological and Geomorphological Sites
- Sites of Importance for Nature Conservation.

9.3.12 Regarding development on land affected by contamination, the NPPF emphasises the requirement to understand the ground risks, and on the development of appropriate remediation to make ground hazards material considerations during the planning process.

9.3.13 The NPPF states that planning policies and decisions should contribute to and enhance the natural and local environment by preventing new and existing

development from contributing to, being put at unacceptable risk from, or being adversely affected by, unacceptable levels of land instability.

9.3.14 It also states that planning policies and decisions should ensure that a site is suitable for its proposed use taking account of ground conditions and any risks arising from land instability. This includes risks arising from natural hazards or former activities such as mining, and any proposals for mitigation including land remediation (as well as potential impacts on the natural environment arising from that remediation).

9.3.15 Indirect impacts associated with land stability mitigation, such as damage to the landscape or ecological receptors have been considered within their respective chapters.

Local policy

9.3.16 The *Cotswold District Local Plan to 2031*[4] provides guidance for development planning within the Cotswolds Area of Outstanding Natural Beauty (AONB). It provides information on the spatial strategy and emphasises the value and sensitivity of geodiversity, including guidance on the protection of geodiversity in accordance with international, national and local status and recommends mitigation.

9.3.17 Development shall conserve and enhance biodiversity and geodiversity, avoid adverse impact on existing features as a first principle and enable net gains by designing in opportunities for geological conservation alongside new development. Appropriate mitigation or compensation would be required to enable the benefits of a development at a nationally designated site to clearly outweigh the impact it is likely to have on the special features and national network of SSSI.

9.3.18 The *Cotswolds AONB Management Plan (2018-2023)* [5] highlights the following special qualities of the Cotswolds (relevant to geology and soils):

- Limestone geology – including its visible presence as natural and artificial outcrops (i.e. worked ground such as quarries and road cuttings), use as building material, and through the plant and animal communities it supports, e.g. internationally important flower-rich limestone grasslands and ancient broadleaved woodland.
- The Cotswold escarpment – including views to and from it.
- The High Wolds – a large open, elevated landscape with commons, ‘big’ skies and long-distance views.
- River valleys – the majority forming the headwaters of the Thames, with high quality water.

9.3.19 The following policies set out in the *Cotswolds AONB Management Plan* are relevant to geology and soils:

- *Policy CE2* (Geology): the geological features of the Cotswolds AONB should be conserved and enhanced through effective management. Opportunities should be sought to promote awareness and understanding of the geological features of the Cotswolds AONB. Proposals that are likely to impact on the geological features of the Cotswolds AONB should have regard to these features and seek to conserve and enhance them. Exploration and research

into the geology of the Cotswolds AONB should be continued in order to improve understanding of the landscape, and of the geological resource and its importance to inform the conservation and management of geological and geomorphological sites.
- *Policy CC5* (Soils): Soil degradation should be halted and reversed by managing soils in a way that: (i) increases organic content, water retention and carbon sequestration; and (ii) reduces erosion, water pollution and compaction. Soil management should be a key component of future agri-environment, land management and rural development support mechanisms in the Cotswolds AONB.

9.3.20 The *Tewkesbury Local Borough Plan to 2011*[6] Policy NCN3 and Pre-Submission version of the *Tewkesbury Borough Plan* (PSTBP)[7] Policy NAT1 is relevant to geodiversity and applies to designated geological sites. It states that development likely to result in the loss, deterioration or harm to features of importance to geological conservation, either directly or indirectly, would not be permitted unless:

- The need for, and benefits of, the development clearly outweigh its likely impact on the local environment, or the nature conservation value or scientific interest of the site.
- It can be demonstrated that the development could not reasonably be located on an alternative site with less harmful impacts.
- Measures can be provided (and secured through planning conditions or legal agreements), that would avoid, mitigate against or, as a last resort, compensate for the adverse effects likely to result from development.

9.3.21 The *Gloucester, Cheltenham and Tewkesbury Joint Core Strategy* (JCS)[8] 2011-2031 (adopted December 2017) presents a co-ordinated strategic development plan for 2011 to 2031 for the three authorities. The following policies are relevant to geology and soils:

- *Policy SD6*: new developments should seek to protect the character of the landscape, considering the landscape and visual sensitivity of the area.
- *Policy SD7*: all development proposals in or within the Cotswolds AONB are required to conserve and, where appropriate, enhance its landscape, scenic beauty, wildlife, cultural heritage and other special qualities, consistent with the policies set out in the *Cotswolds AONB Management Plan*.
- *Policy SD9*: the biodiversity and geological resource of the JCS area should be conserved and enhanced on designated sites, ensuring that new development within and surrounding such sites has no unacceptable adverse impacts. New development should be encouraged to contribute positively to biodiversity and geodiversity whilst linking with wider networks of green infrastructure. A Geodiversity Action Plan is likely to be developed for Gloucestershire during the lifetime of the JCS, that would provide more detailed advice on the conservation of geodiversity. Developers and local authorities should work with appropriate partner organisations including the Local Nature Partnership and Gloucestershire Geology Trust to deliver enhancements.

9.3.22 The *Minerals Local Plan for Gloucestershire (2018-2032)* (adopted March 2020) replaced the Gloucestershire Minerals Local Plan (1997-2006) Saved Policies (adopted 2007) and has been developed to focus on achieving sustainable development. The management of mineral resources is essential to support:

9.3.23 Local Planning Authority flood management plans and policies, as detailed in ES Appendix 13.1 Water legislative and policy framework (Document Reference 6.4) and ES Chapter 13 Road drainage and the water environment (Document Reference 6.2), have been considered.

Guidance and standards

9.3.24 This ES has been undertaken with due consideration of the following:

- Geotechnics, General Information, Managing Geotechnical Risk, CD 622 [9].
- DMRB LA 104 Environmental assessment and monitoring[10].
- DMRB LA 109 Geology and soils[11].
- *Contaminated Land Statutory Guidance*, Department for Environment, Food and Rural Affairs (Defra), 2012[12].
- *Land contamination: risk management*[13] (replacing Model Procedures for the Management of Land Contamination (CLR11) Defra and Environment Agency)
- CIRIA R132: A Guide for Safe Working on Contaminated Sites[14].
- CIRIA SP73: Roles and Responsibility in Site Investigations[15].
- BS 5930: 2015 + A1:2020: Code of Practice for Site Investigations[16].
- BS 10175:2011 + A2 2017: Code of Practice for Investigation of Potentially Contaminated Sites[17].
- *Groundwater protection guidance*[18], including The Environment Agency's approach to groundwater protection[19].
- CIRIA C552: Contaminated Land Risk Assessment, A guide to good practice[20].
- CIRIA C681: Unexploded ordnance (UXO) A guide for the construction industry[21].
- CIRIA C733: Asbestos in soil and Made Ground: a guide to understanding and managing risks[22].
- CIRIA C765: Asbestos in soil and Made Ground: good practice site guide[23]
- *Eurocode 7 (BS EN 1997-1*[24] and *EN 1997-2*[25]) and all relevant normative guidance.
- Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention (Environment Agency)[26]
- Construction Code of Practice for the Sustainable Use of Soils on Construction Sites (Defra)[27].
- Agricultural Land Classification: protecting the best and most versatile agricultural land (Natural England)[28].

9.3.25 Whilst the environmental impact of certain ground risks, such as contaminated land, are considered within this chapter, the assessment and management of risk associated with land instability are excluded from this chapter in accordance with DMRB LA 109 Geology and soils, which states; "*Risks associated with geotechnical hazards and land stability are assessed in CD622, Managing geotechnical risk*." Land stability and sinkholes are considered in ES Appendix 4.4 Major accidents and disasters long list and short list. ES Appendix 9.2 Preliminary ground investigation report (Preliminary GIR) (Document Reference 6.4), contains an appendix presenting the current land stability risk assessment, to be developed at detailed design stage.

9.4 Assessment methodology

General approach

9.4.1 The methodology for assessing the construction and operational impacts for geology and soils is in accordance with LA 104 *Environmental assessment and monitoring*[29] and LA 109 *Geology and soils*[30].

9.4.2 ES Appendix 4.2 Responses to scoping opinion (Document Reference 6.4) and ES Appendix 4.5 Changes to scope and methodology (Document Reference 6.4) outline the changes in scope and methodology since the submission of the Scoping Report in May 2019.

9.4.3 LA 109 *Geology and soils* require the baseline scenario to be informed by desk study information presented in a preliminary sources study report and existing survey data, where available. In accordance with this methodology, assessment process follows the following key stages:

- Undertake desk-based review and historical information review.
- Establish outline study area and baseline scenario.
- Establish the potential for significant effects based on the scoping questions in LA 109 *Geology and soils.*
- Where likely significant effects are identified, complete a detailed baseline scenario.
- Finalise study area based on the scheme design and baseline scenarios.
- Establish design and mitigation measures.
- Undertake assessment of likely significant effects.
- Undertake monitoring where significant effects are reported.

Conceptual site model

9.4.4 Contaminated Land, as defined in Part IIA of Environmental Protection Act 1990, is assessed through the identification and assessment of pollutant linkages (contaminant-pathway-receptor relationships). Implicit in the guidance is the application of risk assessment to assess whether potential pollutant linkages may be significant. The meanings of the components are:

- Contaminant - a contaminant or pollutant that is in, on or under the land and that has the potential to cause harm or pollution.
- Pathway: a route by which a receptor is or could be affected by a contaminant.
- Receptor: a target that could be adversely affected by a contaminant, for example a person, controlled waters (in this case surface water or groundwater), an organism, property or an ecosystem.

9.4.5 The development of a Conceptual Site Model (CSM) for the scheme has been undertaken in accordance with Environment Agency's advice on *Land contamination: risk management*[31](replacing the now withdrawn *CLR11 Model Procedures for the Management of Land Contamination*).

9.4.6 In accordance with *CIRIA 552 guidance*[32], for a potential risk to either environmental or human receptors to exist, a plausible pollutant linkage involving each of these components must exist. If one of the components is absent then a pollutant linkage, and thereby potentially unacceptable risk, is also unlikely to exist. Where all three components are or may be present, a potentially complete

pollutant linkage can be considered to exist. This does not automatically imply the presence of unacceptable risk, but further investigation of the potential pollutant linkages is required.

Tier 1 Preliminary Risk Assessment

9.4.7 The process comprises a tiered approach, commencing with a Tier 1: Preliminary Risk Assessment. This involves the identification of potential pollutant linkages, the determination of hazards (hazard identification) and subsequent hazard assessment, as well as risk estimation and risk evaluation of the posed hazard identified in the CSM.

9.4.8 The CSM is based on the baseline studies presented in Table 9-2, and have been informed by available ground investigations and extensive desk-based information for the site.

9.4.9 In relation to the potential impacts of construction, the CSM has been developed with consideration of the construction processes that are anticipated to be required – i.e. to allow construction of the scheme. This includes the following proposed works:

- Construction of earthworks (including earth embankments and excavations).
- Piling.
- Installation of drainage (highway and ground stabilisation) and culverts.
- De-trunking works along the existing alignment.

9.4.10 Any pollution linkages deemed to pose a ‘moderate’ risk or greater at Tier 1: Preliminary Risk Assessment, in accordance with best practice guidelines CIRIA C552, have been subjected to further risk assessment in the form of a Tier 2: Generic Quantitative Risk Assessment (GQRA).

Tier 2: GQRA methodology

9.4.11 In this assessment, soil and groundwater contamination data gathered through intrusive ground investigations have been screened against published guideline values based on the relevant receptors considered in the CSM.

Controlled waters

9.4.12 Where a potential pollution linkage is identified in relation to controlled waters a Tier 2: GQRA is undertaken on available data. Where impact of groundwater onto surface waters is being assessed, this is achieved by screening available water chemical testing results against the Environmental Quality Standards (EQS) for annual average inland surface water (freshwater) values. Assessing the impact on drinking water resources is achieved by screening available water chemical testing results against UK Drinking Water Standards. Impacts from hazardous leachable contaminants on the underlying groundwater are assessed by comparing minimum reporting values against measured concentrations.

9.4.13 Where the EQS are dependent on bioavailability, which is the case for copper, lead, manganese, nickel and zinc, the bioavailable fractions have been derived using the UKTAG Metal Bioavailability Assessment Tool.

Ground gas

9.4.14 Where a potential pollution linkage is identified in relation to ground gas, an initial screening exercise was undertaken based on a review of the potential for ground gas generation undertaken in accordance with *CIRIA C665* and *CL:AIRE RB17*. Based on this initial assessment the requirement for further intrusive ground gas monitoring was derived.

9.4.15 Due to the nature of the scheme, i.e. no new buildings are included within the development, the assessment involves only derivation of Gas Screening Values (GSVs) based on recorded maximum concentrations of methane and carbon dioxide, and the measured maximum gas flow. The derived GSV is then compared to GSV thresholds to obtain a risk classification.

9.4.16 The Tier 1: Preliminary Risk Assessment and Tier 2: GQRA human health and controlled waters risk assessments have been undertaken based on findings of the ground investigation works and laboratory testing recorded in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). For the purposes of the ES it is a complete and robust baseline. The risk assessments are summarised in Section 9.7 Baseline conditions and are presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).

Human health

9.4.17 Where a potential pollution linkage is identified in relation to human health a Tier 2: GQRA is undertaken on available data. This is done by screening available soil chemical test results against published generic assessment criteria for a suitable land use scenario, such as Defra *Category 4 Screening Levels*, and where these are not available, *the Land Quality Management /The Chartered Institute of Environmental Health Suitable 4 Use Levels*. The considered land use scenarios are based on the CSM and include open public space (park), residential without plant uptake and commercial end-use generic scenarios.

9.4.18 The applied assessment criteria, as per paragraph above, have been derived using the Environment Agency Contaminated Land Exposure Assessment model. This model defines age classes for receptors within a number of generic end use scenarios.

Identification of baseline conditions

9.4.19 The baseline studies for specific topic areas is listed in Table 9-2. The identification of baseline conditions for geology is primarily based on desk study information included within ES Appendix 9.1 Preliminary Sources Study Report (Document Reference 6.4) and Phase 2A ground investigation information presented in ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4), and with interpretation presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). The identification of baseline conditions for soils is primarily based on the ALC survey information included within ES Appendix 9.6 Agricultural land classification report (Document Reference 6.4)

Table 9-2 Baseline studies

Topic	References
Geology	• Mott MacDonald Sweco Joint Venture (2018). A417 Missing Link Preliminary Sources Study Report. (HA GDMS Ref 30509), included as ES Appendix 9.1 Preliminary Sources Study Report (Document Reference 6.4). • Edward J Wilson and Associates (1990) Addendum to Geomorphological Survey at Crickley Hill (A417) (HA GDMS Ref 21576). • Edward J Wilson and Associates (1988) Report on Geomorphological Survey at Crickley Hill (A417) (HA GDMS Ref 12609). • Relevant historical geomorphological maps extracted from these reports are provided within Historical Geomorphological Plans (ES Appendix 9.1 Preliminary sources study report (Document Reference 6.4)). • A417 Crickley Hill Improvements – Geotechnical Investigations and Proposed schemes for Road Widening on the northern Valley Side, report by Professor John Hutchinson (1991)[33] (HA GDMS Ref 12597). • WSP (2002) A417Crickley Hill Improvement scheme Preliminary Sources Study (HA GDMS Ref 16772)[34]. • WSP (2003) A417 Cowley to Brockworth bypass Improvement Preliminary Sources Study Report (HA GDMS Ref 18693)[35]. • WSP (2004) A417 Cowley to Brockworth bypass Improvement Geomorphological Survey Report (HA GDMS Ref 18694)[36]. • British Geological Survey (BGS) 1:50,000 scale geological map of Gloucester (Solid and Drift) Sheet 234[37]. • BGS 1:50,000 scale digital geological map, available on the 'Onshore GeoIndex' viewer[38]. • BGS 1:10,560 scale geological maps of Gloucestershire Sheets SO91SW[39] and SO91NW[40]. • BGS Bristol and Gloucester regional geology guide, 3rd edition[41] . • Geology of the Cirencester district: BGS memoir for 1:50,000 geological sheet 235[42]. • Topographic survey undertaken for the scheme. • Factual information from recent ground investigations included in ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4) with interpretation presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). • Findings from site walkovers carried out on 7-8 August 2019, 29 August 2019, 10 October 2019 and 7 November 2019, reported in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4)). • Information from historical ground investigations, listed in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). • Interpretation of desk and field based geomorphological mapping, reported in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). • Historical borehole records available from BGS Onshore GeoIndex[43].
Current and historical land use	• Envirocheck report for Crickley Hill – A417. Reference 213224-1-1, prepared by Landmark Information Group (2002). • Groundsure Envirosight: A417 Missing Link. Reference COGL14R011, prepared by Groundsure Environmental Intelligence Solutions (2014). • Findings from a site walkover carried out in April 2017, reported in ES Appendix 9.1 Preliminary sources study report (Document Reference 6.4).

Topic	References
	• Groundsure Enviro Insight reports (2019) for A417 Missing Link. Reference ARUP_1, ARUP_2, ARUP_3, prepared July 2019 – included as ES Appendix 9.4 Groundsure enviro insight reports (Document Reference 6.4). • Findings from recent geo-environmental investigations carried out in 2019/20, reported within ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).
Soil survey	• N A Duncan and Associates (2004) A417 Cowley to Brockworth Bypass Improvement, Soil and Agricultural Land Classification Report[44] • WSP (2006) A417 Cowley to Brockworth Bypass Improvement Scheme Stage 2 Land Use Report[45] • Natural England 1:250,000 Agricultural Land Classification Map South-West Region (ALC006)[46] • ADAS (2021) A417 Missing Link, Birdlip, Gloucestershire – Agricultural Land Classification, included as ES Appendix 9.6 Agricultural land classification report (Document Reference 6.4)

Assessment of likely significant effects

9.4.20 The process for assessment of likely significant effects is outlined as follows:

- Step 1: assess the value (sensitivity) of receptors, shown in Table 9-3, as per Table 3.11 in LA 109 *Geology and soils.*
- Step 2: assess the magnitude of impact on receptors, shown in Table 9-4, as per Table 3.12 in LA 109 *Geology and soils*.
- Step 3: derive impact significance from receptor value and magnitude of impacts, shown in Table 9-5, as per Table 3.8.1 in LA 104 *Environmental assessment and monitoring*. The significance of effect is determined by comparison of the identified value (sensitivity) of the receptors with the magnitude of the effect. For the purpose of this assessment, values of moderate adverse and above have been defined as significant effects, and mitigation measures are necessary.

Table 9-3 Environmental value (sensitivity) and descriptions of receptors

Receptor value (sensitivity)	Receptor type	Description
Very high	Geology	• Very rare and of international importance with no potential for replacement (e.g. UNESCO World Heritage Sites, UNESCO Global Geoparks, SSSIs and GCR where citations indicate features of international importance). Geology meeting international designation citation criteria which is not designated as such.
	Soils	• Soils directly supporting an EU designated site (e.g. Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar), and/or • ALC grade 1 and 2 or Land Capability for Agriculture (LCA) grade 1 and 2.
	Contamination	• Human health: very high sensitivity land use such as residential or allotments. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

Receptor value (sensitivity)	Receptor type	Description
		• Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
High	Geology	• Rare and of national importance with little potential for replacement (e.g. geological SSSI, Area of Special Scientific Interest (if in Northern Ireland), NNR). Geology meeting national designation citation criteria which is not designated as such.
	Soils	• Soils directly supporting a UK designated site (e.g. SSSI), and/or • ALC grade 3a, or LCA grade 3.1.
	Contamination	• Human health: high sensitivity land use such as public open space. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
Medium	Geology	• Of regional importance with limited potential for replacement (e.g. RIGS). Geology meeting regional designation citation criteria which is not designated as such.
	Soils	• Soils supporting non-statutory designated sites (e.g. Local Nature Reserves (LNR), Local Geological Sites (LGS), Sites of Nature Conservation Importance (SNCI)), and/or • ALC grade 3b or LCA grade 3.2.
	Contamination	• Human health: medium sensitivity land use such as commercial or industrial. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
Low	Geology	• Of local importance/interest with potential for replacement (e.g. non-designated geological exposures, former quarries/mining sites).
	Soils	• ALC grade 4 and 5 or LCA grade 4.1 to 7, and/or • Soils supporting non-designated notable or priority habitats.
	Contamination	• Human health: low sensitivity land use such as highways and rail. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
Negligible	Geology	• No geological exposures, little/no local interest.
	Soils	• Previously developed land formerly in 'hard uses' with little potential to return to agriculture.
	Contamination	• Human health: undeveloped surplus land/no sensitive land use proposed. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

Receptor value (sensitivity)	Receptor type	Description
		• Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

Table 9-4 Magnitude of impact and typical descriptions

Magnitude of impact (change)	Receptor type	Typical description
Major	Geology	• Loss of geological feature/designation and/or quality and integrity, severe damage to key characteristics, features or elements.
	Soils	• Physical removal or permanent sealing of soil resource or agricultural land (>20ha).
	Contamination	• Human health: significant contamination identified. Contamination levels significantly exceed background levels and relevant screening criteria (e.g. category 4 screening levels) with potential for significant harm to human health. Contamination heavily restricts future use of land. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
Moderate	Geology	• Partial loss of geological feature/designation, potentially adversely affecting the integrity; partial loss of/damage to key characteristics, features or elements.
	Soils	Permanent loss/reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction, erosion of soil resource.), including: • Physical removal or permanent sealing of 1ha-20ha of agricultural land. • permanent loss/reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction, erosion of soil resource).
	Contamination	• Human health: contaminant concentrations exceed background levels and are in line with limits of relevant screening criteria (e.g. category 4 screening levels). Significant contamination can be present. Control/remediation measures are required to reduce risks to human health/make land suitable for intended use. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
Minor	Geology	• Minor measurable change in geological feature/designation attributes, quality or vulnerability; minor loss of, or alteration to, one (maybe more) key characteristics, features or elements.
	Soils	• Temporary loss/reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction, erosion of soil resource).

Magnitude of impact (change)	Receptor type	Typical description
	Contamination	• Human health: contaminant concentrations are below relevant screening criteria (e.g. category 4 screening levels). Significant contamination is unlikely with a low risk to human health. Best practice measures can be required to minimise risks to human health. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
Negligible	Geology	• Very minor loss or detrimental alteration to one or more characteristics, features or elements of geological feature/designation. Overall integrity of resource not affected.
	Soils	• No discernible loss/reduction of soil function(s) that restrict current or approved future use.
	Contamination	• Human health: contaminant concentrations substantially below levels outlined in relevant screening criteria (e.g. category 4 screening levels). No requirement for control measures to reduce risks to human health/make land suitable for intended use. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).
No change	Geology	• No temporary or permanent loss/disturbance of characteristics, features or elements.
	Soils	• No loss/reduction of soil function(s) that restrict current or approved future use.
	Contamination	• Human health: reported contaminant concentrations below background levels. • Surface water: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). • Groundwater: refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

Table 9-5 Significance matrix

		Magnitude of impact (degree of change)				
		No change	Negligible	Minor	Moderate	Major
Environmental value (sensitivity)	Very high	Neutral	Slight	Moderate or large	Large or very large	Very large
	High	Neutral	Slight	Slight or moderate	Moderate or large	Large or very large
	Medium	Neutral	Neutral or slight	Slight	Moderate	Moderate or large
	Low	Neutral	Neutral or slight	Neutral or slight	Slight	Slight or moderate
	Negligible	Neutral	Neutral	Neutral or slight	Neutral or slight	Slight

Consultation

9.4.21 Consultations with Natural England, the National Trust, the Environment Agency and Gloucestershire County Council have informed the development of the geology and soils assessment. These discussions have focused on the geodiversity and environmental aspects of the scheme. Engagement is ongoing and is documented in the Statement of Common Ground appended to the Statement of Commonality (Document Reference 7.3).

9.5 Assessment assumptions and limitations

General

9.5.1 The assessment undertaken for geology and soils has been based on the collation and evaluation of available documentation listed in Table 9-2.

9.5.2 Details of the ground stabilisation measures would be developed at detailed design. For the purpose of the assessments it has been assumed that these would incorporate drainage solution that extends to the DCO Boundary.

Soil resources

9.5.3 The assessment of ALC has been based on a number of recent or previous detailed ALC surveys as follows:

- 2020/21 ADAS surveys to provide detailed survey information focussed in the offline section of the scheme.
- 2004 N.A. Duncan & Associates Ltd survey in support of the previous A417 Cowley to Brockworth Bypass, covering the extent of the current A417 route.
- Post 1988 Agricultural Land Classification data sourced from MAGIC Maps and updated from surveys undertaken previously in the western extent of the scheme.
- Pre-1988 Agricultural Land Classification data sourced from MAGIC Maps where the above datasets do not cover the full extent of the red line area.

9.5.4 In compiling the ES Figure 9.6 Agricultural land classification (Document Reference 6.3), the above data has been applied in date order, ensuring that the most recent data is used as a priority where there may be slight overlaps in survey area.

9.5.5 Having compiled the various datasets from the 2020/21 ALC survey and previous surveys undertaken for historic iterations of the scheme, a few areas of land within the DCO Boundary were identified as being excluded from the detailed survey scope. This reflects both red line changes since point of survey as well as areas of land that have fallen between survey scope and include:

- A small triangle of land (circa 1.1ha) forming part of a wider parcel in the west of the scheme required for essential ecological mitigation and to accommodate a new access to Flyup 417 Bike Park. Survey information for the wider land parcel confirm the land as Grade 3a.
- Small areas of land (circa 1.4ha) in the vicinity of the Air Balloon roundabout, Emma's Grove and Crickley Ridge.
- An area of land (circa 6.1ha) between the 2004 and 2020/21 survey data to the north of the Cowley roundabout. Some of this area would be sealed by the

proposed A417 whilst some would be returned to current use following construction.

9.5.6 All these areas were identified as ALC grade 3 land using the Pre-1988 data from Natural England. For the purpose of assessment, it has therefore been assumed that this area is ALC grade 3a.

9.5.7 The assessment of the likely effects on agricultural land would rely on the accuracy of these datasets and information as provided by third parties. For those areas not surveyed, a worst-case assessment has been undertaken by including the land as Grade 3a. In total, these areas represent circa 8.6ha which equates to 6.6% of the total agricultural land affected by the scheme or 4.3% of the total land within the scheme boundary.

Limits of deviation

9.5.8 An assessment has been conducted within the Limits of Deviation (LoD) outlined within ES Chapter 2 The project (Document Reference 6.2).

9.5.9 The assessment of the impact of the scheme on geology and soils has considered potential impacts within the proposed vertical and horizontal LoD. The baseline conceptual site model has considered all potential contaminant linkages (formed due to the construction and/or operational phases of the scheme) and all potential effects on human health and controlled waters.

9.5.10 Minor changes to the alignment of the scheme within the LoD are not considered likely to give rise to any new effects, or to any materially worse adverse or better beneficial effects from those predicted in the assessment.

9.6 Study area

9.6.1 The scheme study area for this chapter comprises the DCO Boundary and an additional buffer of 500 metres, as shown in ES Figure 9.1 Study area (Document Reference 6.3). This area is considered appropriate for the consideration of historical and current potentially contaminative land uses, which could be impacted by, or impact on the scheme. Where there is potential for sources of contamination outside the 500 metre buffer to migrate on-site, these have been included in the assessment and presented in this ES.

9.6.2 The study area also considers the location of sensitive receptors that could be affected by the scheme within the 1 kilometre buffer (such as controlled water receptors like aquifers and surface water below/down-gradient of study area, water abstraction points including Source Protection Zones (SPZ), or land users and neighbours). The potential receptors have been identified and are listed in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). As noted within ES Chapter 13 Road drainage and the water environment, the study area was extended beyond 1 kilometre following a risk-based approach for the River Churn and the headwaters to the River Churn.

9.6.3 For other receptors, including designated geological sites and BMV agricultural land, the study area comprises the DCO Boundary, as these receptors are only likely to be impacted where the scheme directly crosses or interfaces with them.

9.7 Baseline conditions

Current baseline

9.7.1 The detailed desk study review of the scheme baseline is described in ES Appendix 9.1 Preliminary sources study report (Document Reference 6.4) and ES Appendix 9.2 Preliminary GIR (Document Reference 6.4) and summarised in this section.

Geology

9.7.2 The south-west to north-east trending Cotswold Escarpment dominates the regional landscape[47]. The study area comprises an asymmetrical valley adjacent to Crickley Hill, where the northern slopes are steeper than the southern slopes. The Existing A417 runs along the axis of this valley. Above the escarpment, the landscape comprises an extensive limestone plateau. The topography is presented within ES Figure 9.2 Topography (Document Reference 6.3).

Artificial ground

9.7.3 Artificial ground' is a term used by the BGS for those areas where the ground surface has been significantly modified by human activity. The term includes:

- Made ground — man-made deposits such as embankments and spoil heaps on the natural ground surface.
- Worked ground — areas where the ground has been cut away such as quarries and road cuttings.
- Infilled ground — areas where the ground has been cut away then wholly or partially backfilled.
- Landscaped ground — areas where the surface has been reshaped.
- Disturbed ground — areas of ill-defined shallow or near surface mineral workings where it is impracticable to map made and worked ground separately.

9.7.4 The study area is predominantly agricultural land, where artificial ground is rarely encountered. The artificial ground present in the study area is typically associated with the Existing A417, near access roads or embankments. Previous studies indicated the presence of 'filled ground' at Grove Farm/Crickley Hill Tractors (see ES Appendix 9.1 Preliminary sources study report (Document Reference 6.4)). This area was used as a site compound during the improvement works undertaken on the Existing A417 in the 1960s. It is understood that historical infilled quarries may be present in the area, but the backfill materials used are unknown. Birdlip Quarry is understood to be partially infilled, and fly tipped material is known to be present.

9.7.5 The completed ground investigations have encountered artificial ground within the scheme. It has been recorded as made ground on exploratory holes and for the purpose of the assessments artificial ground has been referred to as made ground. The locations of made ground encountered during recent and historical ground investigations and also areas of worked ground and potentially infilled land are presented in ES Figure 9.7 Land use features plan (Document Reference 6.3).

Superficial deposits

9.7.6 Cheltenham Sand and Gravel is mapped in the western part of the scheme. These deposits are interpreted as products of erosion of the Cotswold escarpment and may have been deposited as alluvial fans, mixed with wind-blown sand.

9.7.7 Alluvium is likely to be deposited within the narrow valley of the tributary of Norman's Brook.

9.7.8 'Mass movement deposits', comprising a variable material of both cohesive and granular materials derived from the Inferior Oolite, Bridport Sand Formation and Lias Group mudstones and accumulated through slope processes, such as landsliding, hillwash, and soil creep, is mapped within the valley adjacent to Crickley Hill and the Churn valley near Shab Hill. Locally, 'mass movement deposits' may contain lenses of peat or organic material.

9.7.9 Tufa is commonly deposited around springs and streams in the Cotswolds. It is formed from alkaline waters, supersaturated with calcite. On emergence from the ground, waters release carbon dioxide due to the lower atmospheric partial pressure of carbon dioxide, resulting in an increase in pH. Since carbonate solubility decreases with increased pH, precipitation is induced. The tufa formation process is described in more detail in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). Tufa deposits may support specialised habitats. These are considered in ES Chapter 8 Biodiversity (Document Reference 6.2).

Bedrock geology

9.7.10 The scheme is underlain by rocks of the Jurassic Lias Group, Inferior Oolite Group, and Great Oolite Group, as presented in ES Figure 9.3 Geological map (Document Reference 6.3). Figure 9.3 presents the BGS published geology for the area with a reinterpreted geology map for the scheme (inside the red dashed line). The lines of evidence that have been used to derive the reinterpreted geological map have been described within ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).

9.7.11 The western part of the scheme study area is underlain by the Lias Group, but the bedrock is largely buried under a cover of 'mass movement deposits'. The Inferior Oolite Group overlies the Lias Group in the Crickley Hill area. The Fuller's Earth Formation, which in turn overlies the Inferior Oolite Group, outcrops at the head of Churn Valley. The formations of the Great Oolite Group Limestone overlie the Fuller's Earth Formation and outcrop across the higher elevated and level terrain across the scheme. To the south, around Cowley, the Great Oolite Group Limestones are absent, resulting in the Fuller's Earth Formation being at outcrop.

9.7.12 The scheme is anticipated to encounter three north-west to south-east trending faults, namely the Shab Hill Barn, Shab Hill, and Stockwell Faults, shown in ES Figure 9.3 Geological map (Document Reference 6.3). In addition, a north-east to south-west trending fault, named Cally Hill Fault has been inferred to extend from Churn Valley towards Stockwell Farm. A north to south trending fault, named Nettleton Bottom Fault, is inferred to extend along the alignment of Nettleton Bottom.

9.7.13 The inferred position of these faults is based on the geomorphological, ground investigation and surface geophysics information, as detailed in the ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). The revised locations are shown on ES Figure 9.3 Geological map (Document Reference 6.3). In addition to the five named faults identified, other zones of increased faulting or rock mass disturbance may also be present locally, which may result in locally increased fracturing within the bedrock and the creation of preferential pathways for groundwater flow. Refer to ES Chapter 13 Road drainage and the water environment (Document Reference 6.2) for more details.

9.7.14 Cavities, gulls and fissures are anticipated close to the edge of the Cotswold Escarpment, predominantly within the Inferior Oolite Group. The formation of gulls and fissures is associated with cambering and dissolution of the limestone bedrock. Refer to ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).

Geological designated sites

9.7.15 Crickley Hill and Barrow Wake SSSI and Knap House Quarry SSSI are designated geological SSSIs located within the study area, as shown in ES Figure 9.5 Designated geological sites (Document Reference 6.3). Both SSSIs are also designated as GCR sites. Crickley Hill and Barrow Wake SSSI is also a designated biological SSSI. Geodiversity aspects are detailed in ES Appendix 9.5 Geodiversity at Crickley Hill and Barrow Wake SSSI (Document Reference 6.4).

9.7.16 The southern slopes of Crickley Hill exhibit the best sections in the Cotswolds of the Crickley Member (formerly ‘Pea Grit’) and overlying coral bed (Scottsquar Member). The lowest part of the exposed sequence of bedrock is one of the very few to show the basal Leckhampton Member (formerly ‘Scissum Beds’), which overlies the Lias Group. Currently the upper part of the sequence is well exposed, as it forms the prominent Crickley Hill escarpment. However, the lower part of the sequence is concealed by a build-up of ‘mass movement deposits’ and vegetation.

9.7.17 The scheme encroaches into Crickley Hill and Barrow Wake SSSI, as shown in ES Figure 9.5 Designated geological sites (Document Reference 6.3). Through consultations with Natural England it is understood that the geological importance is due to the exposure of the Leckhampton Member at the base of the Inferior Oolite. The existing exposures of the Leckhampton Member within the SSSI are located within the DCO Boundary but outside the scheme footprint.

9.7.18 Knap House Quarry SSSI contains important exposures of Middle Jurassic sediments, and the best illustration of the effects of tectonic uplift in between the deposition of the Birdlip Limestone and Salperton Limestone formations (Inferior Oolite Group). The scheme would not pass through Knap House Quarry SSSI and therefore would not result in any impact on the SSSI in this location.

9.7.19 A site walkover was undertaken with Natural England on 7 November 2019 at Crickley Hill and Barrow Wake SSSI to identify the geological boundary between the Lias Group and Inferior Oolite Group, which would, in turn, identify locations where the Leckhampton Member was exposed.

9.7.20 The locations of the existing geological exposures of the Leckhampton Member identified with Natural England are shown on ES Figure 9.5 Designated geological sites (Document Reference 6.3). The easternmost observed exposure

of the Leckhampton Member was found close to existing road level, and largely concealed by dense vegetation. This exposure is located adjacent to the Existing A417, which would become the new Cold Slad Link Road.

9.7.21 The other observed outcrops of the Leckhampton Member were found further to the west, above a bench in the existing cut slope. These geological exposures were also largely concealed by 'mass movement deposits' and vegetation.

9.7.22 The potential impacts on designated sites due to changes of groundwater levels are considered in ES Chapter 13 Road drainage and water environment (Document Reference 6.2).

Hydrology and hydrogeology

9.7.23 The hydrological and hydrogeological baseline conditions are described in full in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2). A summary is provided below.

9.7.24 The tributary of Norman's Brook is a watercourse running from east to west below Crickley Hill and is primarily groundwater fed. It is connected to the River Severn and rises from springs on the escarpment. A small stream was also noted above the escarpment, immediately south of Birdlip junction, which is possibly associated with the Churn valley near Shab Hill.

9.7.25 The limestones of the Great Oolite and Inferior Oolite groups are classified as Principal Aquifers, separated by the less permeable Fuller's Earth Formation (which forms the lowermost formation of the Great Oolite Group). The Lias Group is classified as a Secondary (undifferentiated) Aquifer. The Bridport Sand Formation (the uppermost formation in the Lias) is considered to be in hydraulic continuity with the Inferior Oolite aquifer, though the available ground investigation findings suggest it is not laterally persistent within the study area.

9.7.26 Groundwater flow is largely through secondary fractures and fissures, which can be enhanced by dissolution resulting in tertiary (karstic) porosity features. Fracture density, and therefore groundwater flow, generally increases towards the edge of the escarpment due to cambering and gull-formation within the limestone. The Fuller's Earth Formation acts as an aquitard between the Great Oolite and Inferior Oolite, with localised hydraulic continuity likely to occur where it thins, fractures, or becomes faulted.

9.7.27 Groundwater springs and seepages in the study area generally occur locally at the contact between the more impermeable mudstones in the Upper Lias, and the more permeable limestones of the Inferior Oolite Group or Bridport Sand Formation, and between the limestones of the Great Oolite Group and mudstones of the Fuller's Earth Formation. Springs also emanate from the 'mass movement deposits' found on the slopes along the Cotswold Escarpment and Crickley Hill, where preferential flow paths have developed through more permeable zones of the mixed material. However, the flow pathways are complicated by cambering of the limestone bedrock and the disturbed nature of the 'mass movement deposits'.

Ground investigations

9.7.28 The scheme has been investigated through Phase 1 and Phase 2A investigations between 2019 and 2020. The details are provided below. The locations of the ground investigations are shown in ES Figure 9.4 Ground investigation location

plan (Document Reference 6.3). The findings from these ground investigations have been reviewed to inform the ground conditions interpretation in this chapter, as presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).

9.7.29 The scheme specific ground investigations have been designed to assess and quantify the potential for triple pathway permeabilities that are characteristic of karst aquifers. The groundwater level monitoring network has been designed to ensure that groundwater responses to seasonal fluctuations and storm responses are appropriately recorded and to ensure that where groundwater has the potential to interact with design elements of the proposed road development are appropriately assessed.

9.7.30 In addition, several historical ground investigations have been undertaken within the study area, as summarised in ES Appendix 9.1 Preliminary sources study report (Document Reference 6.4). Where relevant, information obtained from these investigations has informed the assessments.

Phase 1 investigations

9.7.31 The Phase 1 ground investigation was completed between January and February 2019 with the post-field works monitoring still on-going and due to be completed in mid-2021. This comprised eight boreholes within the scheme alignment and its vicinity. The primary purpose of this investigation was to provide initial information on the hydrogeological setting of the scheme. All boreholes were equipped with groundwater monitoring installations. Factual information is presented within ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4). The locations of the exploratory holes are also shown on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3).

9.7.32 It should be noted that Phase 1 boreholes were constructed when option 12 was still under consideration and are spatially distributed to incorporate option 12 and option 30 (the scheme). Details on the alternative options are provided in ES Chapter 3 Assessment of alternatives (Document Reference 6.2).

Phase 2A investigations

9.7.33 Phase 2 investigations followed on directly after the Phase 1. Due to programme constraints Phase 2 scope was revised and split into Phase 2A and 2B. The aim of the Phase 2A investigations was to investigate the full scheme alignment to inform the outline design and environmental impact assessments with respect to ground hazards (including land contamination), and provide further data for hydrogeological baseline. The scope of Phase 2A investigations is detailed in the ground investigation specification[48]. Phase 2B (also referred to as Phase 3) will be completed at the detailed design stage with an aim to gather more detailed information required for that stage of the scheme. As the scheme design has evolved since the initial Phase 2 investigations were proposed, the scope of Phase 2B investigations will be revised and confirmed at the detailed design stage.

9.7.34 The Phase 2A ground investigations commenced in March 2019 and were completed in October 2020. The last Phase 2A groundwater monitoring installation was placed in June 2020. The monitoring of individual groundwater installations commenced immediately after their installation. Groundwater monitoring of all Phase 2A installations will continue until end of June 2021 in

accordance with the ground investigation specification. Data obtained from the ongoing monitoring is not essential for the assessments and will be considered at detailed design.

9.7.35 Phase 2A investigations also included geophysical surveys targeting areas of mass movement materials, geological faulting and potential 'gull' features. The locations of the surveys are shown on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3).

9.7.36 Factual information is presented within ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4). The locations of the exploratory holes are also shown on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3).

9.7.37 The interpretation of the results obtained through the Phase 1 and Phase 2A investigations is presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).

Encountered ground conditions

9.7.38 The encountered ground and groundwater conditions, based on historical ground investigation information and interpretation of Phase 1 and Phase 2A borehole records, are presented in detail in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). The encountered ground conditions are summarised in Table 9-6. The encountered groundwater conditions with detailed interpretation of hydrogeological baseline and impact assessments are presented in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

9.7.39 Ground investigations completed to date indicate that the scheme (other than the areas of existing highway) is predominantly underlain by natural soils, with minor areas of made ground identified. The encountered made ground is shown in ES Figure 9.7 Land use features plan (Document Reference 6.3)

Table 9-6 Summary of ground conditions

Strata	Areas encountered	Proved thickness (m)
Topsoil	Encountered in most holes across the length of the scheme.	0.1-0.4
Made ground	Sporadically encountered between Ch 0+700 and Ch 1+700, Ch 1+850 and Ch 2+500 and Ch 5+000 to 5+860.	Up to 2.6m
Alluvium	Not encountered as part of the Phase 1 and Phase 2A GI and any soft deposits encountered have been considered as part of the mass movement deposits. (Minor areas of alluvium may be present adjacent to the tributary of Norman's Brook, which have not been encountered during the investigations).	Not encountered
Cheltenham sand and gravel	Ch 0+000 to Ch 0+500 Encountered in the lower part of the Crickley Hill valley.	1 to 2m thick
Mass movement	Ch 0+500 to Ch 1+750	0.7 to 22.5m thick

Strata	Areas encountered	Proved thickness (m)
deposits	Below the scheme footprint and on the wider northern and southern slopes of the Crickley Hill Valley.	
	Ch 3+100 On the side slopes of the Churn Valley.	1 to 3.7m
Head	Ch 1+750 to 5+500 Superficial material mobilised due to slope movement processes.	
	Material overlying Inferior Oolite	0.2 to 2.5m thick (typically <1m)
	Material overlying Great Oolite Group - limestone	0.2 to 3.7m (typically <1m)
	Material overlying Fuller's Earth Formation	0.2 to 2.6m (typically 0.3 to 1.5m)
Great Oolite Group – limestone (includes White Limestone and Hampen Formations but not separated out in this GIR)	Ch 2+950 to Ch 3+500 Encountered between the Shab Hill Fault and the Shab Hill Barn Fault – thickest towards the southwest	10 to 15m thick
	Ch 3+500 to Ch 5+500 Sporadically encountered from the south of Ch 3+500	1.5 to 4m thick
Great Oolite Group - Fuller's Earth Formation	Ch 2+900 to Ch 3+000 Encountered from ground surface prior to Shab Hill Fault	1.5m thick
	Ch 3+000 to Ch 3+500 Underlying the GOG limestone between the Shab Hill Fault and the Shab Hill Barn Fault	12m thick
	Ch 3+500 to Ch 4+750 Encountered between the Shab Hill Barn Fault and the Stockwell Fault and partially overlain by the GOG - limestone	5m to 20m thick (>25m where not penetrated)
	CH 4+750 to Ch 5+500 Encountered from ground surface south of the Stockwell Fault	13m thick (>18m where not penetrated)
Inferior Oolite Group	Present beneath the scheme from Ch 1+750 to Ch 5+500. Exposed at surface between Ch 1+750 and Ch 2+920. Beyond Ch 2+920 it underlies the Fuller's Earth Formation. (From Ch 2+050 to Ch 2+600 there is a gap in GI information – to be completed post issue of this GIR)	Formation thicknesses presented below:
	Salperton Limestone Formation	6.5m to 11.5m thick (average 9m)
	Aston Limestone Formation	0.5m to 5.2m thick (average 2m)
	Birdlip Limestone Formation	49m to 55m thick (average 52m)
Lias Group – Bridport Sand Formation	Proved to underlie the IOG from Ch 1+750 to Ch 2+500 and Ch 3+500 to Ch 5+500. To the south	10m to 28m thick (average 19m)

Strata	Areas encountered	Proved thickness (m)
	of the scheme not fully penetrated (more than 37m thick)	
Lias Group – mudstones (includes Whitby Mudstone Formation, Marlstone Rock Formation, Dyrham Formation, Charmouth Mudstone Formation)	Ch 0+000 to Ch 1+700 Encountered beneath the Cheltenham Sands and Gravels and the Crickley Hill mass movement deposits. Upper weathered surface 1.4m to 18m thick overlying mudstone Ch 1+700 to Ch 2+100 Proven below the Bridport Sand Formation (Note that the Marlstone Rock Formation is a thin (up to 1m thick) limestone band that has not been encountered consistently)	Not proven over both chainage extents [Lias group >350m [1]]

Soil resources

9.7.40 Agriculture is the main land use within the areas surrounding the scheme. ES Figure 9.6 Agricultural land classifications (Document Reference 6.3) shows the agricultural land classifications across the scheme.

9.7.41 The principal physical factors influencing agricultural production are climate, site and soil. These factors together with interactions between them form the basis for classifying agricultural land into one of five grades; ALC grade 1 land being of excellent quality and ALC grade 5 land of very poor quality. ALC grade 3 land is divided into two subgrades designated 3a and 3b. BMV agricultural land includes ALC grades 1 to 3a.

9.7.42 An ALC survey was undertaken between October 2020 and January 2021, to determine the ALC of soil resources within the DCO Boundary, where access was available and no previous survey information existed. The result of the ALC survey is presented in ES Appendix 9.6 Agricultural land classification report (Document Reference 6.4) and provides accurate information on the agricultural grade of the land. The survey results in relation to the scheme are shown on ES Figure 9.6 Agricultural land classifications (Document Reference 6.3).

9.7.43 The total area of agricultural land that would be affected by the construction of the scheme has been estimated to be approximately 130.2ha, as shown in Table 9-7.

Table 9-7 Agricultural land affected by the construction of the scheme

ALC grade	Description	Area (ha)
Subgrade 1	Excellent (BMV)	-
Subgrade 2	Very good quality (BMV)	-
Subgrade 3a	Good quality (BMV)	32.0
Subgrade 3b	Moderate quality	75.2
Grade 4	Poor quality	22.9
Grade 5	Very poor quality	-
Total agricultural land affected		130.2

Other land (non-agricultural)	67.9

9.7.44 The scheme would require both temporary (including temporary with permanent rights) and permanent land take, as well as land for wider mitigation and enhancement as part of the scheme. A review of the agricultural land quality within the DCO Boundary was undertaken and is presented in Table 9-8.

Table 9-8 Proportion of ALC types identified to be affected by the scheme

Works	ALC grade	Area (ha)
Permanent Works	Subgrade 3a (BMV)	18.9
Permanent Works	Subgrade 3b	69.36
Permanent Works	Grade 4	19.49
Temporary Works	Subgrade 3a (BMV)	13.13
Temporary Works	Subgrade 3b	5.9
Temporary Works	Grade 4	3.2
TOTAL AGRICULTURAL LAND AFFECTED		**130.2**

9.7.45 Table 9-8 identifies 18.9ha of BMV agricultural land would be permanently lost due to the construction of the scheme, and 13.13ha of BMV land would be temporarily lost, to be reinstated following construction.

Contamination

Site history

9.7.46 The area has historically undergone very little development, aside from the construction of a radio communication station complex in Birdlip c. 1940s. Records of a road along approximately the same route up Crickley Hill as the present day A417 exist from around 1777. It was converted into a two-lane road in the early 1960s. Most recently, closed-circuit television (CCTV) masts were erected mid-slope and at the top of Crickley Hill in around 2009. The site history is described in detail in ES Appendix 9.1 Preliminary sources study report (Document Reference 6.4).

Unexploded ordnance

9.7.47 The summary of the unexploded ordnance (UXO) assessment, presented in ES Appendix 9.1 Preliminary sources study report (Document Reference 6.4), indicates that the UXO risk for the scheme is low.

Historical land use

9.7.48 Most of the features within the study area are related to unspecified old quarries and pits, many of which have since been infilled. For example, Birdlip Quarry was historically mined for limestone, and is the biggest identified infilled quarry within the study area. It is located directly to the north of the proposed Cowley junction and encroaches on the scheme footprint, as shown on ES Figure 9.7 Land use features plan (Document Reference 6.3).

9.7.49 There are no licensed water abstractions or private water supplies within the study area. However, there are known and potential unlicensed surface water, groundwater and potable water abstractions within 1 kilometre of the scheme as

detailed in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

Current land use

9.7.50 No fuel stations have been identified within the study area. However, there are a number of 'tank' features, which based on historical and current land use and their location, are likely to be associated with agricultural irrigation, private water supply, or livestock/farm use. The telecommunications mast and electrical substation associated with Birdlip Radio Station are present adjacent to the scheme. See ES Figure 9.7 Land use features plan (Document Reference 6.3).

Regulatory data

9.7.51 There have been seven records of Environment Agency Recorded Pollution Incidents within the study area. Three incidents did not record any impacts. Three incidents along the Existing A417, close to Air Balloon roundabout, recorded an impact to land (category 3 minor impact). One incident, recorded to the south of the scheme along the B4070, was also classified as category 3 – minor impact.

9.7.52 Eight Licenced Discharge Consents were noted within the study area. Seven were related to sewage discharge of treated effluent, while one was related to domestic soakaway drainage at the Air Balloon public house. These are detailed in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

9.7.53 Six individual landfill cells were indicated, associated with Crickley Lodge, north of the scheme. These cells were used for the disposal of inert waste however no further information is given as to the types of materials disposed.

9.7.54 The above-mentioned pollution incidents, discharge consents and landfill cells may be potential sources of contamination and have been considered in land contamination assessments.

Environmental designations

9.7.55 The off-line section of the scheme is situated in a Nitrate Vulnerable Zone for the protection of both groundwater and surface water.

Conceptual Site Model (CSM)

9.7.56 A CSM has been prepared following the results of the ground investigation, presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4)

Potential sources

9.7.57 The possible sources of contamination have been distinguished into on-site and off-site sources. For the purpose of the CSM, those sources listed as on-site relate to locations within the DCO Boundary. Sources identified outside this area but within the boundaries of the study area are deemed to be off-site sources. Refer to ES Figure 9.7 Land use feature plan (Document Reference 6.3) for DCO Boundary.

9.7.58 The potential baseline sources of contamination are detailed in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4) and are shown on ES Figure 9.7 Land use feature plan (Document Reference 6.3). In summary these include:

- Made ground including:
  - Made ground associated with the existing road infrastructure (engineered fill and road surface that may contain coal tar), private development/farmland (on and off-site).
  - Made ground encountered in ground investigations.
  - Made ground exhibiting potential evidence of contamination such as brick and concrete (fields along the Existing A417 climbing escarpment on-line section), also slag, ash, clinker and hydrocarbon odour (infilled land at Grove Farm/Crickley Hill Tractors), tarmacadam or bituminous surfacing (areas of car parking or road network), as detailed in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).
  - Historical infilled quarries (on and off-site) including Birdlip Quarry.
  - Historical landfill - Crickley Lodge Historical Landfill (6 individual cells) (off-site).
- Activities associated with the operation of the existing road infrastructure (A417 and other routes crossing the proposed scheme) (on and off-site).
- Electricity substation (off-site).
- Agricultural storage and operation (on and off-site).
- Potential fuel spills along the Existing A417 alignment.
- Pollution incidents (on and off-site).
- Electrical mast (off-site).
- Coach hire services (off-site).
- Civil Defence Training Centre (off-site).
- Sewage works (off-site).
- Impacted groundwater from off-site sources.

9.7.59 Made ground and infilled quarries are potential source of ground gas.

9.7.60 The introduction of new sources of contamination, such as fuels and oils used in construction plant; impact on the water environment is presented in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2).

Potential pathways

9.7.61 The pathways associated with potential contamination are detailed in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). A summary of the potential pathways through which contamination sources may come into contact with receptors considered most appropriate for the scheme is provided as follows:

- Soil pathway - Along the existing alignment, the most prevalent pollutant linkages are associated with the ingestion, inhalation, or dermal contact with contaminated ground soils and soil derived dust. Construction workers are likely to be directly exposed to contaminated soils or made ground during the works on site through dermal, ingestion and inhalation. Exposure duration is likely to be relatively short-term.
- Gas pathway - Made ground and the presence of infilled quarries within the DCO Boundary are considered as a potential source of ground gas. However, as there are no areas of confined spaces proposed as part of the scheme, any potential sources of ground gas are considered to be freely venting to the atmosphere and are therefore not considered to present a risk. Hence the inhalation of ground gasses/hydrocarbon vapours is unlikely.

- Groundwater pathway - The leaching of contaminants from site soils as a result of rainwater infiltration is likely in the absence of drainage or hard cover. Additionally, due to the nature of previously encountered strata within the available ground investigations (more permeable strata overlying less permeable materials), vertical and lateral migration of contamination is considered plausible. Increased rainwater infiltration into the ground during excavation works or point discharge into the ground of water removed during dewatering activities may result in mobilisation of contaminates and vertical migration into the underlying groundwater. The presence of gulls and fissures within the rock, particularly in the Crickley Hill escarpment area may provide preferential flow paths for contaminants. Introduction of piled foundations may introduce new pathways for contamination migration.
- Surface water pathway - The proximity of surface water features in relation to the scheme makes the potential of surface run-off or direct discharge of potential contamination into adjacent surface waters a plausible pathway. New drainage or underground service corridors may introduce preferential flow paths for contaminants towards surface water receptors. The surface water features within close proximity to the scheme are illustrated in ES Figure 13.1 Surface water features (Document Reference 6.3).

Potential receptors

9.7.62 Based on the nature of the proposed scheme, the receptors of potential contamination are listed in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4) and summarised below.

9.7.63 The following have been identified as potential human health receptors:

- Residents who live on land parcels adjacent of the DCO Boundary.
- Users of the public rights of way such as walkers, cyclists and horse riders (WCH) including disabled users.
- Regular maintenance workers of the scheme may be exposed to subsurface contamination through inhalation or dermal contact with soil dust. Exposure duration is likely to be relatively short-term, however it is feasible that this could be on a regular basis, over the lifetime of a worker (e.g. grass on cutting verges).

9.7.64 It is unlikely that users of the scheme may be receptors of potential contamination due to relative isolation within vehicles and the transient nature and likely short-term duration of any potential contamination.

9.7.65 Construction workers are likely receptors during construction. Exposures experienced by construction workers are of shorter duration than for future site users due to the limited period of exposure. However, the nature of the exposure may be more severe than for future site users as construction workers may be required to expose, treat, excavate and transport or otherwise engage in close contact with the exposed materials as a necessity.

9.7.66 The following surface water and groundwater receptors have been identified:

- Surface waters and hydrological features.
- Groundwater resources within underlying Principal and Secondary A aquifers along the alignment and associated water abstraction points and source protection zone.

- Groundwater fed surface water features such as springs and streams.

9.7.67 These are shown on ES Figure 13.5 Hydrogeological study areas and features (Document Reference 6.3) and detailed in ES Chapter 13 Road drainage and water environment (Document Reference 6.2).

Tier 1: Preliminary Risk Assessment

9.7.68 The potential contaminant linkages within the conceptual site model, and associated risks identified for the scheme are presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4).

9.7.69 The following potential pollutant linkages potentially posing a 'moderate' risk at baseline conditions have been identified:

- Maintenance workers of the Existing A417 scheme exposed to identified sources via dermal contact.
- WCH including disabled users of land within study area exposed to identified sources by dermal contact with and inhalation of contaminated soils and dust derived from soils.
- Construction workers encountering potentially contaminated soils/materials (known and unexpected), with primarily exposure through the inhalation of soil dusts and direct dermal contact.
- Scheme neighbours (e.g. residents and workers of farms) being exposed to potentially contaminated materials via inhalation and dermal contact with soils or dust during construction works.
- Leaching of contaminants, vertical and horizontal migration within the subsurface or services corridors including drainage towards groundwater, and lateral migration towards surface water receptors.
- Surface run-off towards surface water receptors. Increased potential for contaminated surface run-off to migrate to surface water and groundwater receptors as a result of contaminant mobilisation from uncovered stockpiles.
- Mobilisation of existing contaminants in soil and groundwater as a result of exposure following ground disturbance during construction with increased potential for contaminants in unsaturated soils to leach to groundwater in open excavations.

Tier: 2 GQRA

9.7.70 The results of chemical testing completed on soil and groundwater samples obtained during the Phase 1 and Phase 2A investigations were subjected to Tier 2: GQRA as presented in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). This identified the following:

Human health

9.7.71 The Tier 2: GQRA with respect to human health identified elevated concentrations of Polycyclic Aromatic Hydrocarbons (PAH) compounds in relation to applied assessment criteria for WCH and also A417 maintenance workers. These elevated concentrations were recorded in a single location, DS/RC415 located in the south-eastern part of the Existing A417 (location marked on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3). The overlying tarmacadam may be a potential source of these elevated concentrations.

Controlled waters

9.7.72 The Tier 2: GQRA with respect to controlled waters indicates that generally groundwater low levels of metals with minor isolated exceedances of the applied assessment criteria identified in all monitored hydrogeological units. Similarly, relatively low levels of metals have been measured in surface water with only single and minor exceedances.

9.7.73 The assessment has indicated that made ground has a potential to be a source of leachable metals primarily copper, but also lead, nickel and zinc, which may pose a risk to surface and groundwater receptors. However, the chemical test results indicate that made ground materials are unlikely to have a detrimental impact on groundwater and surface water quality in baseline conditions.

9.7.74 Both groundwater and surface water have however been found impacted by hydrocarbon contaminants such as PAH compounds and petroleum hydrocarbons.

9.7.75 Generally, groundwater was found free of PAH contamination with an exception of a single location. Elevated concentrations of PAH compounds were measured in OH416, located in the south-eastern part of the Existing A417 (location marked on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3). Total concentration of PAH compounds was measured up to 0.027mg/l in sampled groundwater. The potential source of the PAHs is the A417 existing drainage soakaway.

9.7.76 Elevated concentrations of PAH compounds have however been identified in all monitored surface water locations within the study area except for SW6. This includes monitoring location SW2 positioned on the tributary of Norman's Brook. Monitored locations are shown in ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3). Considering the distribution of the identified exceedances across the study area and catchments, these are unlikely to be associated with a specific source and are likely to be reflective of the general background quality of the surface water.

9.7.77 Elevated concentrations of petroleum hydrocarbon compounds were measured in groundwater in DS/RC229 located on the northern Crickley Hill escarpment, OH416 and DS/RC403 both located in the vicinity of the south-eastern part of the Existing A417 and DS/RC224 located on the southern Crickley Hill escarpment near Barrow Wake carpark (location marked on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3).

9.7.78 Groundwater sampled from DS/RC229 on three consecutive occasions contained aliphatic hydrocarbons at between 1.6mg/l and 11mg/l. The source of this contamination has not been identified and the monitored well is located outside the DCO Boundary, approximately 5m to the north. It is possible that the source is associated with properties located to the north of that monitored location. It is likely that this contamination extends into the DCO Boundary.

9.7.79 There is no evidence to indicate that the hydrocarbon impacted groundwater is migrating to the surface water receptors. There have been detected minor concentrations of petroleum hydrocarbon compounds in surface water in monitoring locations SW1 (the culverted section of the tributary of Norman's Brook in Bentham), SW4 (the Frome River) and SW5 (tributary to the Churn

River) albeit below the applied assessment criteria and therefore not considered to be of significance. Monitored locations are shown in ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3).

9.7.80 The DCO Boundary for the online section (climbing the escarpment) at chainage 0+900 extends to the historical inert landfill cell. There is no information available on waste deposited within the landfill cell except that it was inert waste. Inert waste is unlikely to pose a significant risk to the environment, however as environmental standards may have changed since the landfills were established, confirmation of potential risks would be required. No ground investigations have been completed at this stage due to access being hindered by dense vegetation and steep slopes and therefore there is no information on current groundwater quality in this area of the scheme.

Future baseline

9.7.81 In ES Chapter 4 Environmental assessment methodology (Document Reference 6.2), the 'Do-Minimum' and 'Do-Something' scenarios have been set out, with the 'Do-Minimum' scenario representing the future baseline with minimal interventions and without new infrastructure. Potential changes to geology and soils receptors in the future would not be noticeable, e.g. topography is unlikely to change, and the receptor groups are unlikely to be different to those identified in the baseline text above. Therefore, the future baseline would remain as set out above.

9.8 Potential impacts

9.8.1 Mitigation measures incorporated in the design and construction of the scheme are reported as embedded mitigation in ES Chapter 2 The project (Document Reference 6.2) and essential mitigation in Section 9.9 Design, mitigation and enhancement measures. Prior to the implementation of mitigation, the scheme has the potential to affect geology and soils during construction and operation of the scheme, both beneficially and adversely.

Construction

Geology

9.8.2 The construction activities of the scheme including the excavation process for the proposed cuttings, could affect the Crickley Hill and Barrow Wake SSSI designated geological site (see ES Figure 9.5 Designated geological sites (Document Reference 6.3)) and result in the permanent loss or alteration of a small, but rare and nationally important geological exposure located adjacent to the scheme footprint.

9.8.3 The scheme could result in beneficial impacts through the generation of new exposures within the faces of the rock cuttings proposed in the vicinity of the Crickley Hill and Barrow Wake SSSI. This would provide an opportunity to obtain new information on geological formations present within the designated geological site. Other proposed cuttings along the scheme (for example in the area of Shab Hill junction), could also open new rock exposures as new geological features or attributes.

9.8.4 Tufa deposits formed by the precipitation of calcium carbonate at the location of springs could be damaged or concealed due to construction activities.

Soil resources

9.8.5 With regard to soil resources, construction has the potential to result in the following adverse impacts:

- The temporary and permanent loss of BMV agricultural soils through land-take.
- Degradation of soil resources (including damage to soil structure, reduced biological function, mixing of soil types) resulting from soil compaction due to heavy construction vehicle movements, and the exacerbation of soil erosion through handling and storage of soils.
- Change to the function or quality of soil as a resource, including the deposition of dust on sensitive land uses, disruption to drainage, irrigation and water supply systems, unintentional pollution of soil and water courses, and spread of injurious weeds to adjacent agricultural land from soil and material stockpiles. This could lead to the generation of waste soils that cannot be reused elsewhere on the scheme, requiring off-site disposal as waste.

9.8.6 Construction has the potential to result in beneficial impacts to soil through a reduction in soil erosion through improved drainage.

Contamination

9.8.7 The scheme construction would result in introduction of new receptors such as construction workers. In the event of disturbance of contaminated soils or groundwater during construction, and in the absence of any mitigation measures, there is a potential for human, ecological or controlled water receptors to be affected, and for ground conditions to impact on the design of the scheme. In relation to potentially contaminative land uses, the following adverse impacts could potentially arise as a result of construction of the scheme:

- Mobilising existing contamination in soil and groundwater as a result of ground disturbance and de-watering during construction, particularly in areas of known and unexpected contamination.
- Increasing the potential for contaminants in unsaturated soils to leach to groundwater in open excavations during construction.
- Increasing the potential for contaminated surface run-off to migrate to surface water and groundwater receptors as a result of leaching from uncovered stockpiles.
- Introducing new sources of contamination, such as fuels, chemicals and oils used during construction activities, and also imported construction materials.
- Increasing the potential of construction workforces (from handling, storage and exposure) to existing contamination in soil and groundwater (both known and unexpected).
- Creating preferential pathways for the migration of soil and groundwater contamination, for example along new below ground service routes, service ducts, new drainage associated with slope stability measures, new piled foundations and as a result of dewatering.

9.8.8 Construction has the potential to result in beneficial impacts such as the removal or treatment of contaminated soil, with the effect that existing adverse effects on receptors are removed.

Operation

Geology

9.8.9 No impact on geology from the scheme operation is anticipated.

Soil resources

9.8.10 Following the opening of the scheme, soils adjacent to the road may be affected by spray or airborne contaminants generated during routine maintenance and operation of the road (including vehicle emissions) or released during road accidents/emergency situations.

9.8.11 During the operational stage there could be a reduction in soil erosion through improved drainage design and improvement in surface water run-off quality as a result of additional treatment compared to existing conditions.

Contamination

9.8.12 During operation of the scheme, road users, and the road infrastructure maintenance workers would be introduced as new receptors. Any contamination deemed by risk assessment to have posed a significant risk to the scheme, would have been removed or remediated during the construction phase. Previous risk assessment and any subsequent mitigation measures would have already been undertaken to satisfactorily close out any residual risks identified as part of the construction phase.

9.8.13 During the scheme operation there is also a potential for soils used within the scheme (both site won and imported) to pose a risk to controlled waters and human health. Rainwater infiltration contaminated materials in areas of landscaping may result in mobilisation of contaminates and migration into the underlying groundwater and subsequently towards the surface water receptors.

9.9 Design, mitigation and enhancement measures

Embedded mitigation

9.9.1 The scheme has been designed, to avoid and prevent adverse effects on the geology and soils environment through the process of design development and consideration of good design principles. Embedded mitigation measures for geology and soils are reported as part of the scheme description in ES Chapter 2: The project (Document Reference 6.2).

Essential mitigation for construction

9.9.2 A number of essential mitigation measures have been identified to reduce, remediate or compensate likely significant adverse environmental effects.

Geology

9.9.3 A temporary physical barrier would be constructed to protect the identified exposures of the Leckhampton Member within the Crickley Hill SSSI (as shown on ES Figure 9.5 Designated geological sites (Document Reference 6.3)). This would be considered by the contractor in their temporary works design.

Soil resources

9.9.4 Potential impacts specific to contamination impacting on soil resources would be mitigated through the following measures to be incorporated into a Soil Management Plan, to be prepared by the contractor as part of the development of the EMP:

- Works would be undertaken in compliance with the Defra Construction Code of Practice for the Sustainable Use of Soils on Construction Sites[49].
- The source of imported topsoil and subsoil would be investigated carefully with respect to its suitability for the intended use.
- Should imported soils be required, these would require verification prior to use within the scheme.
- Soil sampling, testing and assessment would be defined in an earthworks specification for the construction works. This specification would be prepared in accordance with the Specification for Highway Works, Series 600 Earthworks.
- The Soil Management Plan would detail the areas and type of topsoil/subsoil to be stripped, stripping method, haul routes and the management of the soil stockpiles. This would ensure high standards in the handling, storage and reinstatement of soils during construction.
- Topsoil would be handled only in the appropriate conditions of weather and soil moisture, and with suitable machinery in line with the Defra Construction Code of Practice.
- Topsoil excavated from areas of known high quality agricultural land would be stored separately and, where possible, reused on-site in areas that would be returned to agricultural use.
- The stockpiling of soils would be avoided whenever possible. Where stockpiling is unavoidable, heaps would be tipped loosely and the surface firmed and shaped to shed water. Where soils are to be stockpiled for more than six months the surface would be seeded with a grass/ clover seed mix.
- Where possible, topsoil would be re-used on site as applicable.
- Any soils that do not meet chemical acceptability criteria would be treated or disposed of to a suitably licenced facility.
- A watching brief would be developed to enable unforeseen ground conditions to be addressed if or when encountered on site.
- The movement of traffic would be confined to designated haul routes to reduce the amount of heavy machinery going over soil materials which could cause compaction of soil materials. Such routes would exclude areas of proposed landscaping.

9.9.5 Following the completion of construction activities, agricultural land taken on a temporary basis would be restored and returned to the landowner for unrestricted agricultural use in the same agricultural condition (ALC grade) that currently exists. This would require monitoring as set out in the Soil Management Plan.

9.9.6 With the adoption of appropriate mitigation for the handling and restoration of soils, as part of the EMP presented in ES Appendix 2.1 Environmental Management Plan (Document Reference 6.4), most soils would be able to continue their various ecosystem functions on or off site.

Contamination

9.9.7 An EMP is presented in ES Appendix 2.1 Environmental Management Plan (Document Reference 6.4). This contains measures to ensure that contamination is addressed during construction and unacceptable risks with respect to human health and controlled waters are mitigated.

9.9.8 Measures contained within the EMP are designed to limit the possibility for dispersal and accidental releases of potential contaminants, spread of weeds, and uncontrolled run-off during construction.

9.9.9 The EMP would establish procedures for dealing with unexpected soil or groundwater contamination that may be encountered.

9.9.10 The completed assessments identify required mitigation measures that include further ground investigations and specific risk assessments to identify the source, confirm the risks and design appropriate remediation measures. Verification of any implemented remediation measures would be undertaken prior to construction of the relevant scheme elements and would require site specific monitoring to confirm that the remediation works have been successful and there would be no risk to the receptors from construction or operation of the scheme. These mitigation measures have been outlined in the EMP (ES Appendix 2.1 Environmental Management Plan (Document Reference 6.4)).

Health and safety and pollution control during construction

9.9.11 Potential impacts on human health receptors including off-site receptors would be addressed through the adoption of the following measures, which are included in ES Appendix 2.1 Environmental Management Plan (Document Reference 6.4):

- Dust control – to include the damping of ground with water.
- Sheeting of lorries transporting spoil off site and the use of dust suppression equipment on plant.
- Adequate fuel/chemical storage facilities e.g. bunded tanks, hard standing and associated emergency response spillage control procedures.
- Well maintained plant and associated emergency response/spillage control procedures.
- Any temporary onsite storage of contaminated material would be stored on sheeting and covered to minimise the potential for leachate and run off from the stockpile being generated.
- Health and safety training and provision of suitable welfare facilities.
- Provision and use of Personal Protective Equipment (PPE).

9.9.12 Construction activities would be undertaken in line with current best practice and guidance in accordance with the EMP. Construction-related receptors and sources would be managed to negate their impact on the environment. The commitments incorporated in the EMP include but are not limited to:

- A watching brief for the duration of site works in areas of potential contaminated land or groundwater (by a suitably qualified and experienced person).
- An Action Plan for safely dealing with unexpected contamination.
- Management of construction-related waters.
- Sustainable use of soils on a construction site.
- Environmental monitoring including surface water and ground water monitoring.

- Following the completion of construction groundwater monitoring observation boreholes may be decommissioned. The decommissioning of the boreholes would be done in such a way that the material placed in the observation well mimics the annulus construction.
- Decommissioning of abandoned sewage discharge soakaways within the scheme area.
- Foundation Works Risk Assessments for piling (if undertaken), to identify appropriate piling techniques. The detailed design of underground structures, such as piled foundations would also consider measures to reduce impacts on groundwater flow. For example, deeper and wider spaced piling to reduce flow barrier effects and allow a similar groundwater flow path and incorporating appropriate drainage solutions. A site-specific Foundation Works Risk Assessment (FWRA) would be undertaken to identify appropriate piling methodology. The FWRA would be made available for review by the EA during the detailed design period as per their request made during statutory consultation, as recorded in the Statement of Common Ground (see Statement of Commonality (Document Reference 7.3)).

Essential mitigation for operation

9.9.13 The mitigation measures detailed in ES Chapter 2 The project (Document Reference 6.2) would prevent the pollution of controlled waters during the scheme operational phase.

9.9.14 Potential risks posed to maintenance workers would be mitigated through adherence to appropriate site and task specific health and safety documentation, required for legal compliance.

Enhancement measures

9.9.15 New geological exposures of the Leckhampton Member would be created within the cuttings that are located outside the area of the Crickley Hill and Barrow Wake SSSI. Interpretation boards would be provided as part of the scheme and would be located adjacent to the Cotswold Way crossing, in a vicinity of the new cuttings. This would be developed at detailed design.

9.9.16 For any work required to stabilise or descale the existing rock exposures of the Leckhampton Member and the Crickley Hill Member adjacent to the A417 within the Crickley Hill and Barrow Wake SSSI, measures are taken to enhance these exposures where possible e.g. by lowering the angles of the exposures an removing loose rock blocks. These works could also be monitored by a suitably qualified geologist.

9.9.17 To provide further information on the geology at the Crickley Hill and Barrow Wake SSSI and also in areas of other cuttings e.g. Shab Hill, access would be arranged where possible for Natural England or their nominated specialists for the recording of stratigraphic horizons and sampling of fossils from geological sections during construction, subject to appropriate risk assessment.

9.10 Assessment of likely significant effects

9.10.1 This section presents the assessment of likely significant effects on geology, soils and land contamination resulting from the construction and operation of the scheme.

9.10.2 The assessment of effects takes into account the potential impacts to each receptor following the implementation of embedded and essential mitigation measures to determine the significance of the residual effects.

Construction

Geology

9.10.3 The scheme encroaches into Crickley Hill and Barrow Wake SSSI (of high importance), however it would not directly affect the existing exposures of the Leckhampton Member within the SSSI. This is because there are no proposed engineering works to the existing cuttings/natural slopes to the north of the Cold Slad Lane access road. Therefore, the scheme would result in a negligible impact on the geological importance of the SSSI, with a *permanent slight adverse* effect and not significant.

9.10.4 New exposures would however be opened in highway cuttings located in the vicinity of Crickley Hill and Barrow Wake SSSI, providing geology specialists an opportunity to study rock formations present within the designated area during construction. In addition, other rock exposures would be created along the scheme alignment in other highway cuttings providing a similar benefit. They are all considered to be of low importance. New exposures are considered to have a minor beneficial impact, with a *permanent slight beneficial* effect that is not significant.

9.10.5 The construction of the scheme would conceal tufa deposits that have formed within the vicinity of the tributary of Norman's Brook, as shown on ES Figure 13.5 (Document Reference 6.3). These deposits are of local importance/interest and are not designated, therefore they have a low value. The construction would result in the complete loss of these deposits, however there are numerous springs with tufa deposits within the area. This is therefore considered to result in the partial loss of the feature and a moderate magnitude of impact. Overall, the effect of the scheme on tufa deposits is assessed as *permanent slight adverse* that is not significant.

9.10.6 The assessment of the scheme's impact on the tufaceous vegetation and the hydrogeological value of the springs associated with tufa have been assessed in ES Chapter 8 Biodiversity (Document Reference 6.2) and ES Chapter 13 Road drainage and the water environment (Document Reference 6.2), respectively.

Soil resources

9.10.7 Section 9.7 Baseline conditions and section 9.8 Potential impacts identified that the construction of the scheme would affect ALC grade 3a (BMV) land, which is a high-value receptor, in addition to ALC grade 3b and ALC grade 4 land which are medium- and low-value receptors respectively. There may also be some impacts on land not used for agriculture or urban / developed areas which have a negligible sensitivity value.

9.10.8 The construction of the mainline carriageway would require the permanent acquisition of 18.92ha of BMV agricultural land (ALC grade 3a) as shown on ES Figure 9.6 Agricultural land classification (Document Reference 6.3). This would lead to a moderate magnitude of impact on that land given the permanent sealing of the soil resource. Given the permanent nature of the effect, the loss of BMV

land cannot be mitigated and this therefore leads to an overall effect on the soil resource (BMV ALC grade 3a agricultural land of high value), which is *permanent large adverse* and significant. The effect is assessed as 'large' as it cannot be mitigated and the effect is on BMV agricultural land.

9.10.9 The permanent loss of 69.36ha of ALC grade 3b agricultural land would result in a major magnitude of impact given the permanent sealing of over 20ha of the soil resource. Given the permanent nature of the effect, the loss of agricultural land cannot be mitigated, and this therefore leads to an overall effect on the soil resource (ALC grade 3b agricultural land of medium value), which is *permanent moderate adverse* and significant. This effect is assessed as 'moderate' given the loss is of grade 3b land which is not BMV.

9.10.10 The permanent loss of 19.49ha of ALC grade 4 agricultural land would result in a moderate magnitude of impact given the permanent sealing of 1ha-20ha of the soil resource. Given the lower sensitivity of this receptor (low) and following mitigation, the significance would be *permanent slight adverse* and not significant.

9.10.11 The construction also requires temporary use of land which would take soil out of agricultural use for the period of construction. Following completion of construction, all temporary facilities would be removed, and the soil reinstated in accordance with the agreed end use for the land. The slopes of false cutting sections would be returned to agricultural use. The agricultural soil temporarily displaced by the scheme would, after land restoration, generally be able to fulfil its primary soil functions on-site. This would be managed through the Soil Management Plan to be developed by the contractor as part of the EMP and would ensure the soil is returned to its current ALC grade.

9.10.12 The temporary loss of 13.1 ha of ALC grade 3a agricultural land would result in a minor impact given the temporary loss of soil function. Given proposal to manage soils during construction and return the land to agriculture, combined with the high value of Grade 3a land, the effect would lead to a *temporary slight adverse* effect which is not significant.

9.10.13 The temporary loss of 5.9 ha of ALC grade 3b agricultural land would result in a minor impact given the temporary loss of soil function. When combined with the medium value of the resource and considering mitigation to manage and restore agricultural land following construction, this would lead to a *temporary slight adverse* impact, which is not significant.

9.10.14 The temporary loss of 3.2 ha of ALC grade 4 agricultural land would result in a *minor* impact given the temporary loss of soil function. When combined with the low value of the resource and considering mitigation to manage and restore agricultural land following construction, this would lead to a *neutral* effect, which is not significant.

Contamination

9.10.15 The assessment of risks from contamination on human health and controlled waters during construction is reported in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). The assessment includes the development of a CSM for the construction phase of the scheme, qualitative Tier 1: Preliminary Risk Assessment and a Tier 2: GQRA of available results. This is summarised below.

Human health

9.10.16 The Tier 1: Preliminary risk assessment identified construction workers and scheme neighbours (WCH and nearby residents) as primarily receptors of the identified sources of contamination during construction as a result of direct exposure to soils and dust generated during ground breaking activities.

9.10.17 The Tier 2: GQRA for the construction scenario identified elevated concentrations of PAH compounds, which may pose a risk to construction workers. These elevated concentrations were measured in DS/RC415 located in the vicinity of the south-eastern part of the Existing A417 and DS/RC419 located in Barrow Wake car park (location marked on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3). The overlying tarmacadam may be a potential source of these elevated concentrations. Elevated concentrations were also identified in CP106, located in Grove Farm/Crickley Hill Tractors area. Slag inclusions were identified in the sampled strata and these are the likely source of PAH compounds.

9.10.18 Similarly, the elevated concentrations of PAH compounds identified in DS/RC415 may pose a risk WCH as a result of dust generation during the construction works in that area.

9.10.19 However, on application of essential mitigation no significant effects on human health during construction have been identified. Therefore, overall the effect of the scheme on risks from contamination on human health for off-site users during construction is assessed *neutral* and not significant. For on-site users this is assessed as *temporary slight adverse* and not significant.

Controlled waters

9.10.20 The Tier 1: Preliminary Risk Assessment identified both groundwater and surface water within the scheme area and its vicinity as potential receptors of the identified sources of contamination. Construction activities may result in that contamination mobilisation and migration towards these receptors or in direct discharge of contaminants to groundwater or surface water, resulting in pollution. The scheme may also introduce new pathways for contamination migration along new drainage or deep foundations.

9.10.21 The Tier 2: GQRA identified elevated concentrations of petroleum hydrocarbon and PAH compounds in groundwater, which may pose a risk to groundwater and/or surface water receptors during construction particularly if dewatering is required or groundwater is intercepted during construction of the slope stabilisation drainage solution.

9.10.22 The drainage would create a pathway for migration of groundwater impacted by petroleum hydrocarbons (encountered in DS/RC229) and groundwater impacted by historical inert waste landfill cell adjacent to the DCO Boundary into the tributary of Norman’s Brook, posing a risk to the controlled water receptor.

9.10.23 Groundwater impacted by petroleum hydrocarbon contamination in DS/RC403, where 0.35mg/l of aliphatic hydrocarbon compounds was measured on one occasion. Minor excavations would be undertaken in the vicinity of DS/RC403, which may encounter groundwater impacted by hydrocarbon contamination and may require dewatering. If discharged into the ground or surface water, it may pose a risk to the controlled water receptor.

9.10.24 In addition, leachable metals within made ground primarily copper but also lead, nickel and zinc. These may pose a risk to surface and groundwater receptors during construction as a result of increased rainfall infiltration or surface run-off.

9.10.25 Although the Tier 2: GQRA have identified localised areas where elevated contamination levels may pose a risk to the controlled water receptors during construction, on application of essential mitigation no significant effects on controlled waters during construction have been identified. Therefore, overall the effect of the scheme on risks from contamination on groundwater during construction is assessed as *neutral* and *slight adverse* and not significant. For surface water this is assessed as *neutral* and *permanent slight adverse* and not significant.

Summary of residual effects during construction

9.10.26 A summary of the residual effects on geology, soils and receptors for contaminated land during construction of the scheme is presented in Table 9-9.

Table 9-9 Summary of effects during construction

Potential impact	Receptor	Description	Receptor sensitivity	Design and mitigation measures	Magnitude of impact	Residual significance of effect
Concealment and loss of tufa deposits in the vicinity of the tributary of Norman's Brook, as shown on ES Figure 13.5 (Document Reference 6.3).	Geology	Tufa deposits formed by precipitation of calcium carbonate	Low	Water features survey carried out to understand location and extent of tufa deposits and site specific factors influencing calcium carbonate deposition.	Moderate	Slight adverse
Damage or loss of geological features of national importance at Crickley Hill and Barrow Wake SSSI	Geology	Identified sensitive existing exposures of the Leckhampton Member	High	Scheme encroaches on SSSI boundary but does not directly impact the exposures. A temporary physical barrier would be constructed to protect the identified exposures of the Leckhampton Member within the Crickley Hill SSSI from construction activities. This would be considered by the contractor in their temporary works design.	Negligible	Slight adverse
New exposures created in highway cuttings including vicinity of Crickley Hill and Barrow Wake SSSI and Shab Hill.	Geology	New rock exposures opened in cuttings where rock faces are exposed providing benefit in the form of an increased understanding of the geology.	Low	N/A	Minor	Slight beneficial
Enhancement measures such as improving existing designated rock exposures and allowing access for Natural England during construction	Geology	Enhancement measures would provide additional benefit in the form of an increased understanding of the geology.	High	N/A	Minor	Slight beneficial

Potential impact	Receptor	Description	Receptor sensitivity	Design and mitigation measures	Magnitude of impact	Residual significance of effect
Permanent loss of ALC grade 3A agricultural land	ALC grade 3A agricultural land		High	N/A	Moderate	Large adverse
Permanent loss of ALC grade 3B agricultural land	ALC grade 3B agricultural land		Medium	N/A	Major	Moderate adverse
Permanent loss of ALC grade 4 agricultural land	ALC grade 4 agricultural land		Low	N/A	Moderate	Slight adverse
Temporary loss of ALC grade 3A agricultural land	ALC grade 3A agricultural land		High	The scheme footprint has been reduced and designed to avoid BMV agricultural land and to reduce impacts on soil resources. Where agricultural uses are to be resumed on land disturbed during the construction of the scheme, these areas would be returned to agricultural use. Soils management plan would be developed to incorporate good practice techniques would be adopted in the handling, storage and reinstatement of soils in these areas to avoid any reduction in the long-term capability and quality of the disturbed land.	Minor	Slight adverse
Temporary loss of ALC grade 3B agricultural land	ALC grade 3B agricultural land		Medium		Minor	Slight adverse
Temporary loss of ALC grade 4 agricultural land	ALC grade 4 agricultural land		Low		Minor	Neutral
Exposure to soil contamination	On-site users	Construction workers	Medium	Appropriate health and safety management systems would be in place during construction including provision of personal protective equipment. Information would be provided to the contractor in accordance with the Construction (Design and Management) Regulations 2015, on potential sources, including desk study and ground investigations (e.g. evidence of contamination and/or soil and groundwater chemical testing), to inform health and safety risk assessments during construction works. Measures contained within the EMP (ES Appendix 2.1 EMP (Document Reference 6.4)) including soils handling and storage, dust control and dealing with	Minor	Slight adverse
	Off-site users	Residents of nearby propoerties	Very high		No change	Neutral
		WCH (Public open space users)	High		No change	Neutral

Potential impact	Receptor	Description	Receptor sensitivity	Design and mitigation measures	Magnitude of impact	Residual significance of effect
				known and unexpected contamination would control the impact resulting in a low and very low risk to these receptors. Tier 1: Preliminary Risk Assessment and Tier 2: GQRA, informed by available information on potential sources including desk study, and ground investigations (e.g. evidence of contamination and/or soil and groundwater chemical testing) have been completed. No requirement for remediation measures has been identified. Risks would be managed through assessment of suitability for reuse in accordance with EMP and associated Materials Management Plan (MMP) (ES Appendix 2.1 Environmental Management Plan (Document Reference 6.4)) and therefore only materials suitable for end use, i.e. those that would not pose an unacceptable risk to human health, would be reused. Unacceptable materials would be removed from site.		
Contaminated soil, leachate/ groundwater/ direct discharge and pollution of aquifers Vertical and lateral migration of leachate/ groundwater contamination and/or direct contact with soil contamination	Groundwater	Inferior Oolite and Great Oolite - Principal Aquifers	High	Tier 1: Preliminary Risk Assessment and Tier 2: GQRA, informed by available information on potential sources including desk study, and ground investigations (e.g. evidence of contamination and/or soil and groundwater chemical testing) have been completed. Areas of concern have been identified, subject to additional investigations and site specific assessments, remediation measures may be required. This would be presented in a remediation strategy.	Negligible	Slight adverse
		Superficial deposits - Secondary A aquifer	Medium		Negligible	Neutral
		Lias Group - Secondary (undifferentiated) aquifer	Low		Negligible	Neutral

Potential impact	Receptor	Description	Receptor sensitivity	Design and mitigation measures	Magnitude of impact	Residual significance of effect
Contaminated soil, leachate/ groundwater/ direct discharge and impact on surface watercourses Pollution migration through new drainage installed as part of slope stabilisation measures Pollution migration along piles/ underground structures	Surface water	Tributary of Horsbere Brook	Medium	The impact would be controlled through measures set out in the EMP (ES Appendix 2.1 EMP (Document Reference 6.4)) including appropriate hazardous materials storage and handling, pollution response and environmental management, materials management and dealing with known and unexpected contamination. Pollution control systems would be targeting areas of concern identified through the risk assessments. The drainage design would prevent/reduce the risk of discharging pollutants into the aquifers via drainage pathways and control surface water runoff at its source. Further details on the drainage design are reported in Appendix 13.10 Drainage report (Document Reference 6.4). Materials reused within the scheme in accordance with EMP and associated MMP (ES Appendix 2.1 Environmental Management Plan (Document Reference 6.4)) and therefore only materials suitable for end use, i.e. those that would not pose an unacceptable risk to controlled waters, would be reused. FWRA to be completed for individual structures where deep foundations or ground improvement works are proposed, to be confirmed subject to the design at detailed design stage.	Negligible	Neutral
		Tributary of Norman's Brook	Medium		Negligible	Neutral
		River Frome and its tributaries	High		Negligible	Slight adverse
		Tributary of River Churn	Medium		Negligible	Neutral

Operation

Geology

9.10.27 The operation of the scheme would result in no change to geology resources resulting in a *neutral* effect which is not significant.

Soil resources

9.10.28 No further impacts are anticipated beyond those occurring during the construction phase. No additional mitigation measures are required.

Contamination

9.10.29 The assessment of risks from contamination on human health and controlled waters during scheme operation is reported in ES Appendix 9.2 Preliminary GIR (Document Reference 6.4). The assessment includes the development of a CSM during operation of the scheme, qualitative Tier 1: Preliminary Risk Assessment and a Tier 2: GQRA of available results. This is summarised below

Human health

9.10.30 The Tier 1: Preliminary Risk Assessment identified routine maintenance workers and scheme neighbours (WCH and nearby residents) as primarily receptors of the identified sources of contamination within the DCO Boundary during scheme operation.

9.10.31 The Tier 2: GQRA for the scheme operation scenario identified elevated concentrations of PAH compounds in soils in DS/RC415 located in the south-eastern part of the Existing A417 (location marked on ES Figure 9.4 Ground investigation location plan (Document Reference 6.3). If reused within the scheme, these materials may pose a risk to end users of the Air Balloon Way and WCH within the scheme vicinity, as well as maintenance workers. However, on application of essential and embedded mitigation no significant effects on human health during operation have been identified. Therefore, overall the effect of the scheme on risks from contamination on human health for off-site users during operation is assessed *neutral* and *permanent slight beneficial*, which is not significant. For on-site users this is assessed as *neutral* and *permanent slight beneficial*, which is not significant.

Controlled waters

9.10.32 The Tier 1: Preliminary Risk Assessment identified site won soils reused within the scheme as a new potential source of contamination with respect to both groundwater and surface water within the scheme area and its vicinity. Rainwater or groundwater infiltration through these materials may mobilise contaminants and result in contamination migration towards these receptors resulting in pollution.

9.10.33 The Tier 2: GQRA indicated that leachable metals within made ground as well as hydrocarbon contamination may pose a risk to surface and groundwater receptors if made ground is reused in landscaped areas or close proximity to surface water receptors, or the scheme introduces changes to the ground surfacing resulting in increased rainwater infiltration and subsequent increased leaching potential of

contaminants into the groundwater. However, on application of essential mitigation no significant effects on human health during operation have been identified. Therefore, overall the effect of the scheme on risks from contamination on groundwater during scheme operation is assessed as *slight adverse* and not significant. For surface water this is assessed as *neutral* and *permanent slight adverse* and not significant.

Summary of residual effects during scheme operation

9.10.34 A summary of the residual effects on geology, soils and receptors for contaminated land during operation of the scheme is presented in Table 9-9.

9.10.35 Mitigation measures with respect to drainage are detailed in Chapter 13: Road Drainage and the Water Environment, Section 13.8.

Table 9-10 Summary of effects during operation

Potential impact	Receptor	Description	Receptor sensitivity	Design and mitigation measures	Magnitude of impact	Residual significance of effect
Exposure to soil contamination	On-site users	Maintenance workers	Medium	N/A	Negligible	Slight beneficial
		Highway users	Low		No change	Neutral
	Off-site users	Residents of nearby properties	Very high		No change	Neutral
		WCH (Public open space users)	High		Negligible	Slight beneficial
Leaching and migration of contaminants due to rainwater infiltration from soils used in construction to groundwater and lateral migration to surface water in areas of landscaping Surface run-off to surface water in areas of landscaping from soils used in construction	Groundwater	Inferior Oolite and Great Oolite - Principal Aquifer	High	N/A	Negligible	Slight adverse
	Surface water	Tributary of Horsbere Brook	Medium		Negligible	Neutral
		Tributary of Norman's Brook	Medium		Negligible	Neutral
		River Frome and its tributaries	High		Negligible	Slight adverse
		Tributary of River Churn	Medium		Negligible	Neutral

9.11 Monitoring

9.11.1 As no significant effects have been identified for the geology and land contamination assessment, no monitoring of significant effects is proposed.

9.11.2 In relation to the agricultural land, the scheme would have significant adverse residual effects on agricultural land due to the amount of land required permanently and temporarily in order to construct and operate the scheme.

9.11.3 Although significant effects have been identified due to the permanent acquisition of grade 3a and grade 3b agricultural land, it is not possible to mitigate these effects, or therefore provide any monitoring.

9.11.4 Where agricultural land is proposed to be used temporarily during construction, monitoring is required as part of the proposed mitigation measures despite these temporary effects not being significant. The land would be restored and returned to the landowner through measures outlined in the Soil Management Plan to be developed by the contractor as part of the EMP. In this instance, post construction monitoring would be required to determine whether pre-existing agricultural soil capability had been reinstated.

9.11.5 Soil conditions would also be monitored in areas of proposed calcareous grassland and woodland creation in order to ensure soil is of an appropriate condition to support the establishment of the proposed mitigation. Monitoring would be undertaken in the opening year and five years after. Such monitoring requirements would be detailed in the Soil Management Plan.

9.12 Summary

9.12.1 In summary, it is considered that there are no significant construction or operation stage effects in relation to geology. Some significant effects are however identified in relation to soil resources and the loss of agricultural land to facilitate the construction of the scheme.

Construction assessment

9.12.2 With appropriate mitigation, construction of the scheme is not considered to result in a significant effect on the designated geological features at Crickley Hill and Barrow Wake SSSI or tufa deposits. The scheme is considered to have no significant effect on geology or contaminated land during construction.

9.12.3 The permanent loss of ALC grade 3A and ALC grade 3B agricultural land which would occur during the construction stage of the scheme, would result in significant adverse effects on ALC grade 3A and ALC grade 3B agricultural land.

Operational assessment

9.12.4 With mitigation measures in place, the scheme is considered to have no significant effect on geology, soils resources or contaminated land during operation of the scheme.

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