# A417 Missing Link
TR010056

# 6.2 Environmental Statement
# Chapter 13 Road Drainage and the Water Environment

Planning Act 2008

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

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**The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009**

# A417 Missing Link

## Development Consent Order 202[x]

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**6.2 Environmental Statement**
**Chapter 13 Road Drainage and the Water Environment**

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# 13 Road drainage and the water environment

## 13.1 Introduction

13.1.1 This chapter of the Environmental Statement (ES) reports the potential impacts of 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 road drainage and the water environment following the methodology set out in the Design Manual for Roads and Bridges (DMRB) LA 113 Road drainage and the water environment.

13.1.2 The chapter describes the methodology used to assess potential impacts of the scheme, the assumptions and limitations of the assessment, a definition of the study area, the baseline condition of the existing water environment in the study area, potential impacts during the construction and operational phases, design mitigation (including embedded and essential mitigation) and enhancement measures, an assessment of likely effects and their significance, and mitigation measures or monitoring deemed necessary.

13.1.3 For the purposes of this chapter, the water environment is considered to comprise:

- Surface water features within the study area.
- Groundwater contained within aquifer units that underlie the study area.
- Other water bodies or water dependent features that may potentially be affected.
- The aspects of potable water supply that directly depend on water resources (e.g. private wells).

13.1.4 The assessment considers the potential effects on the quality and quantity of surface and groundwaters, geomorphology and flood risk that may result from construction activities, the operational road drainage, and accidental spillages.

13.1.5 Associated effects on ecology (including aquatic ecology) are considered in ES Chapter 8 Biodiversity (Document Reference 6.2), although ecological proxy indicators of water quality are considered in section 13.10 Assessment of likely significant effects in this chapter. Effects on ground conditions and water quality arising from existing land contamination are considered in ES Chapter 9 Geology and soils (Document Reference 6.2).

13.1.6 Hazard events assessed and addressed within this chapter (flooding, water pollution and landslip) are detailed in section 4.9 Major accidents and disasters of ES Chapter 4 Environmental assessment methodology (Document Reference 6.2) and ES Appendix 4.4 Major accidents and disasters long list and short list (Document Reference 6.4).

## 13.2 Competent expert evidence

13.2.1 The Road drainage and water environment chapter lead and technical reviewer of the surface water components of the ES chapter and its appendices is a water environment specialist holding an MSc in Catchment Dynamics and Management (University of Leeds). They are a Chartered Water and Environmental Manager (C.WEM), Chartered Scientist (CSci), Chartered Environmentalist (CEnv) and are a Practitioner Member of the Institute of Environmental Management and Assessment (IEMA).

13.2.2 The technical reviewer of the groundwater components of this chapter and relevant associated appendices is a specialist in limestone hydrogeology, with 21 years' experience as a hydrogeologist. They hold a PhD in limestone hydrogeology (University of Huddersfield), an MSc in engineering geology (University of Durham) and is a chartered PGeo and EurGeol.

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

## 13.3 Legislative and policy framework

13.3.1 References to the relevant legislation and policy considered are provided in the following sections.

13.3.2 Full details of relevant legislation, policy and strategy are provided in ES Appendix 13.1 Water legislation, policy and guidance (Document Reference 6.4).

### Legislation

- The Environmental Permitting (England and Wales) (Amendment) (EU Exit) Regulations 2019.
- The Environment (Amendment etc.) (EU Exit) Regulations 2019.
- Environmental Protection Act 1990.
- Environment Act 1995.
- The Environmental Permitting Regulations 2016.
- Water Resources Act 1991.
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (WFD).
- Land Drainage Act 1991.
- Water Act 2014.
- Water Resources (Abstraction and Impounding) Regulations 2006.
- The Water Abstraction and Impounding (Exemptions) Regulations 2017.
- Flood Risk Regulations 2009.
- The Water Supply (Water Quality) Regulations 2018.
- Flood and Water Management Act 2010.
- The Environmental Damage (Prevention and Remediation) (England) Regulations 2015.
- The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.
- The Groundwater (Water Framework Directive) (England) Direction 2016.
- The Conservation of Habitats and Species Regulations 2017.
- The Conservation of Habitats and Species (Amendment) (EU Exit). Regulations 2019).

### Policy

National policy

- National policy statement for national networks (2014) (NPSNN).
- National Planning Policy Framework (2019) (NPPF).
- Planning Practice Guidance.

13.3.3 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 NPSNN.

13.3.4 Table 13-1 identifies the NPSNN policies relevant to road drainage and the water environment and then specifies where in the ES chapter information is provided to address the policy.

**Table 13-1 Relevant NPSNN policies for road drainage and the water environment assessment**

| Relevant NPSNN paragraph reference | Requirement of the NPSNN | Where in the ES chapter is information provided to address this policy. |
|---|---|---|
| 4.36 to 4.47 | NPSNN sets out the need to take effects of climate change adaption into account, and the impacts of climate change when planning location, design, build and operation should be considered. An environment statement should set out how the scheme will take account of the projected impacts of climate change. | Climate adaption is covered in detail in ES Chapter 14 Climate (Document Reference 6.2). It is also considered in section 13.4 Assessment methodology and section 13.8 Potential impacts of this chapter where relevant.<br><br>Climate change factors are included in ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4). |
| 4.48 to 4.56 | NPSNN sets out the need for pollution control and other environmental protection regimes, including consenting and licensing regimes.<br><br>Pollution control involves the prevention of pollution using measures to stop or limit the releases of substances from different sources to the environment to the lowest practicable level. It also ensures that water quality meets standards that guard against the impacts to the receiving environment or human health.<br><br>It requires that the scheme takes into account the full account of environmental impacts, which may require close cooperation with the Environment Agency and other bodies, to ensure that in the case of pollution events they are satisfied that potential releases can be adequately regulated under the relevant pollution control framework.<br>It also requires that cumulative effects of pollution, including that from existing sources and the scheme are considered. | These are outlined in Annex G Ground and surface water management plan of ES Appendix 2.1 Environmental Management Plan (EMP) (Document Reference 6.4) and section 13.9 Design, mitigation and enhancement measures of this chapter. It is also considered throughout section 13.10 Assessment of likely significant effects.<br>Cumulative effects are assessed in ES Chapter 15 Assessment of cumulative effects (document reference 6.2). |

| Relevant NPSNN paragraph reference | Requirement of the NPSNN | Where in the ES chapter is information provided to address this policy. |
|---|---|---|
| 5.90 to 5.115 | NPSNN sets out how flood risk impacts should be considered, including that flood risk will not be increased elsewhere and is only appropriate in areas at risk of flooding where it can be demonstrated that:<br>• The most vulnerable development is located in areas of lowest flood risk unless there are overriding reasons to prefer a different location.<br>• Development is appropriately flood resilient and resistant, including safe access and escape routes where required.<br>• Any residual risk can be safely managed, including by emergency planning.<br>• Priority is given to the use of sustainable drainage systems (SuDS).<br>The Flood Risk Assessment should:<br>• Consider the risk of all forms of flooding arising from the scheme (including in adjacent parts of the United Kingdom), in addition to the risk of flooding to the scheme, and demonstrate how these risks will be managed and mitigated (where relevant), so that the development remains safe throughout its lifetime.<br>• Consider the impacts of climate change, clearly stating the development lifetime over which the assessment has been made.<br>• Consider the vulnerability of those using the infrastructure, including arrangements for safe access and egress.<br>• Include a residual risk assessment after mitigation measures have considered and demonstrate that they are acceptable for the scheme.<br>• Consider if there is a need to remain operational during a worst-case flood event over the schemes' lifetime.<br>• Provide the evidence for the Secretary of State to apply the Sequential Test and Exception Test, as appropriate. | Baseline flood risk is outlined in section 13.7 Baseline conditions of this chapter.<br>Flooding impacts are considered in section 13.8 Potential impacts and section 13.10 Assessment of likely significant effects of this chapter.<br>A Flood Risk Assessment is included as ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4), and its findings have been used to assess the impact of the scheme on flood risk. |

| Relevant NPSNN paragraph reference | Requirement of the NPSNN | Where in the ES chapter is information provided to address this policy. |
|---|---|---|
| 5.219 to 5.231 | NPSNN considers the assessment of impacts to water quality and resources.<br>The proposal has considered to the relevant River Basin Management Plans and the requirements of the WFD.<br>An environmental statement should describe:<br>• The existing quality of waters affected by the scheme.<br>• Existing water resources affected by the scheme and the impacts of the scheme on water resources.<br>• Existing physical characteristics of the water environment (including quantity and dynamics of flow) affected by the scheme and any impact of physical modifications to these characteristics.<br>• Impacts of the scheme on waterbodies or protected under the WFD and source protection zones (SPZs) around potable groundwater abstractions.<br>• Cumulative effects. | Existing quality of waters is included in section 13.7 Baseline conditions and impacts on existing water resources is included in section 13.8 Potential impacts and section 13.10 Assessment of likely significant effects.<br>Existing physical characteristics of the water environment are included in ES Appendices 13.2 WFD compliance assessment to 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).<br>Impacts of WFD waterbodies is considered in ES Appendix 13.2 WFD compliance assessment (Document Reference 6.4) and impacts on SPZs are considered in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4).<br>Cumulative effects are assessed in ES Chapter 15 Assessment of cumulative effects (document reference 6.2). |

<u>Regional policy</u>

- *Thames and Severn Cycle 2 River Basin Management Plans* (RBMPs) *2015-2021*.
- *Thames and Severn Flood Risk Management Plans* (FRMPs) *2015-2021.*

<u>Local policy, strategy and evidence</u>

- *Gloucestershire Local Flood Risk Management Strategy* (2014)*.*
- *Gloucestershire County Council Strategic Flood Risk Assessment Level 1 (2008).*
- *Gloucestershire SuDS Design and Maintenance Guide (2015).*
- *Gloucestershire County Council: Flood Risk Assessment Guidance Note (March 2015).*
- *Cotswold District Local Plan (2011-2031).*
- *Gloucester, Cheltenham and Tewkesbury, Joint Core Strategy 2011-2031*
- *Tewkesbury Borough Plan 2011-2031* (2020).
- *Cotswolds Area of Outstanding Natural Beauty (AONB) Management Plan 2018-2023.*
- *Tewkesbury Borough Council Flood and Water Management Supplementary Planning Document (2019).*

### Guidance and standards

13.3.5 The assessment methodology is based upon DMRB *LA 104 Environmental assessment and monitoring* (LA 104) and *LA 113 Road drainage and the water enviroment*.

13.3.6 Due reference has been made to GOV.UK guidance for preventing pollution[1], working on or near water[2] and for managing water on land[3].

13.3.7 Construction Industry Research and Information Association (CIRIA) guidance used for the assessment includes:

- *Control of Water Pollution from Construction Sites – Guide to Good Practice* (SP156).
- *Control of Water Pollution from Construction Sites – Guidance for Consultants and Contractors* (C532).
- *Control of Water Pollution from Linear Construction Projects – Technical Guidance* (C648).
- *Control of Water Pollution from Linear Construction Projects – Site guide* (C649).
- *Environmental good practice on site* (C692).
- *Groundwater control: design and practice (second edition)* (C750).
- *The SuDS Manual* (C753).
- *Guidance on the construction of SuDS* (C768).

## 13.4 Assessment methodology

13.4.1 The assessment methodology followed for the ES conforms to the standards of LA 104 and LA 113. LA 104 and LA 113 provide a methodology and criteria for assessing the impact of a proposed road scheme on the water environment.

13.4.2 This standard methodology comprises the following steps:

- Definition of a study area (as defined in section 13.6 Study area).
- Identification of potential water receptors within the study area to form baseline conditions, based on the features outlined in Table 13-2, as per Table 3.69 of LA 113.
- Assessment of the potential importance or value (hereafter referred to as value) and sensitivity of each of these receptors, shown in Table 13-3, as per Table 3.70 of LA 113.
- Assessment of the potential magnitude of any construction or operation impact on the receptor, shown in Table 13-4, as per Table 3.71 of LA 113.
- Assessment of the overall significance of any effects on receptors due to impacts, shown in Table 13-5, as per Table 3.8.1 of LA 104. The significance of effect is determined by a combination of the identified importance/sensitivity of the receptor with the estimated magnitude of the effect, considering embedded and essential mitigation. For the purpose of this assessment, values of moderate and above have been defined as likely significant effects.

13.4.3 The methodology for assessing effects is based on the principle that the environmental effects of the scheme, in relation to surface water and groundwater receptors, should be determined by identifying the potential receptors, assigning receptor’s value, assessing the magnitude of change the scheme would have on the resource’s significance (where significance is defined as the attributes that give the resource its value) and then combining these two elements to identify the significance of effect.

13.4.4 In accordance with LA 113 a 'simple assessment' has been conducted for:

- Routine runoff and surface water quality.
- Hydromorphology.
- Spillage and water quality.
- Groundwater level and flow.
- Groundwater quality and routine runoff.
- Groundwater-dependent terrestrial ecosystems (GWDTEs).

13.4.5 A 'simple assessment' involves "the collection and assessment of data and information that is readily available to reach an understanding of the likely environmental effects of a project". Following a 'simple assessment', a detailed assessment may be required to be undertaken as per the methodology detailed in Table 3.2 of LA 113 and this will be outlined. This may include further assessment at detailed design.

13.4.6 Specific methods of assessment required by LA 113 in relation to particular construction and operational impacts are described in more detail in paragraphs 13.4.17 to 13.4.20 and 13.4.21 to 13.4.45 for construction and operation impacts, respectively.

13.4.7 The approach for simple assessments for the operational phase is outlined in the sections 13.4.22 to 13.4.45, with the methodology following the following DMRB assessments:

- ES Appendix 13.2 WFD Compliance Assessment (Document Reference 6.4).
- ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4).
- ES Appendix 13.4 Water Quality Assessment (Document Reference 6.4).
- ES Appendix 13.5 Hydromorphology Assessment (Document Reference 6.4).
- ES Appendix 13.6 Spillage Risk Assessment (Document Reference 6.4).
- ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).
- ES Appendix 13.8 Groundwater Dependant Terrestrial Ecosystems Assessment (Document Reference 6.4).

13.4.8 ES Appendix 4.5 Changes to scope and methodology (Document Reference 6.4) outlines the changes in scope and methodology since the submission of the Scoping Report in May 2019.

### Identification of receptors

13.4.9 The methodology for identifying potential water receptors within the study area, based on the features outlined in Table 13-2 and adapted from Table 3.69 of LA 113, includes undertaking a desk-based review of potential receptors within the study area (defined in section 13.6) and site walkovers and investigations (detailed in sections 13.7.1 to 13.7.3).

### Table 13-2 Attributes and indicators of quality for water features

| Feature | Attribute | Indicator of quality | Possible measure |
|---|---|---|---|
| Watercourse | Water supply/ quality | Amount used for water supply (potable)<br>Amount used for water supply (industrial/ agricultural)<br>Chemical water quality | Location and number of abstraction points<br>Volume abstracted daily<br>WFD chemical status |
| | Dilution and removal of waste products | Presence of surface water discharges<br>Effluent discharges | Daily volume of discharge (treated/untreated) |
| | Recreation | Access to river<br>Use of river for recreation | Length of river used for recreation (fishing, water sports)<br>Number of clubs |
| | Value to economy | Value of use of river | Length of river used for recreation commercially<br>Number of people employed<br>Length of riverbank developed<br>Length of river fished commercially |
| | Conveyance of flow | Presence of watercourses | Number and size of watercourses, natural, artificial or heavily modified water body<br>Number of watercourses artificially managed to control flow/levels |
| | Biodiversity | Biological water quality | Fisheries quality |
| | | Fisheries quality | Fish status, as defined in the WFD |
| Floodplain | Conveyance of flow | Presence of floodplain<br>Flood flows | Developed area within extent of floodplain affected, as determined from hydraulic modelling<br>Flood risk<br>Mean annual flood |
| Groundwater | Water supply/ quality | Amount used for water supply<br>Amount used for water supply (industrial/agricultural) | WFD groundwater quantitative and chemical status<br>Catchment abstraction management Strategy (CAMS) status<br>Location and number of abstraction points<br>Volume abstracted daily and use (potable most important)<br>Location and grade of Source Protection Zone (SPZ) |
| | Soakaway | Presence of soakaways or other discharges to the ground | Location, type and number of discharge points.<br>Daily volume discharged |
| | Vulnerability | Groundwater vulnerability | Classification of aquifer vulnerability |
| | Economic value | Extent of use for abstractions | Number of people employed, cost of alternatives |

| Feature | Attribute | Indicator of quality | Possible measure |
|---|---|---|---|
| | Conveyance of flow | Presence of groundwater supported watercourses<br>Potential for groundwater flooding<br>Groundwater interception by road structures or drainage | Changes to groundwater recharge, levels or flows<br>Number and size of watercourses fed by baseflow |
| | Biodiversity | Presence of GWDTE | Changes to groundwater recharge, levels or flows.<br>Status or classification of wetland including GWDTE under WFD |

### Assessment of value

13.4.10 The value of each water environment feature within the study area (defined in section 13.6) was determined according to the DMRB criteria set out in Table 13-3, as per Table 3.69 of LA 113.

**Table 13-3 Estimating the value of water environment attributes**

| Value | Criteria | Attribute | |
|---|---|---|---|
| Very High | Nationally significant attribute of high importance | Surface water | Watercourse having a WFD classification shown in a River Basin Management Plan (RBMP) and $Q_{95}$ (flow exceeded 95% of the time) ≥1.0 $m^3/s$<br>Site protected/designated under UK legislation (Special Area of Conservation (SAC), Special Protection Area (SPA), Site of Special Scientific Interest (SSSI), Ramsar site, salmonid water) /Species protected by EC legislation Ecology and Nature Conservation |
| | | Groundwater | Principal aquifer providing a regionally important resource and/or supporting a site protected under UK legislation Ecology and Nature Conservation<br>Groundwater locally supports GWDTE<br>SPZ1 |
| | | Flood risk | Essential infrastructure or highly vulnerable development |
| High | Locally significant attribute of high importance | Surface water | Watercourse having a WFD classification shown in a RBMP and $Q_{95}$ <1.0$m^3/s$<br>Species protected under EC or UK legislation Ecology and Nature Conservation |
| | | Groundwater | Principal aquifer providing locally important resource or supporting a river ecosystem<br>Groundwater supports a GWDTE<br>SPZ2 |
| | | Flood risk | More vulnerable development |
| Medium | Of moderate quality and rarity | Surface water | Watercourses not having a WFD classification shown in a RBMP and $Q_{95}$ >0.001$m^3/s$ |

| Value | Criteria | Attribute | |
|---|---|---|---|
| | | Groundwater | Aquifer providing water for agricultural or industrial use with limited connection to surface water<br>SPZ3 |
| | | Flood risk | Less vulnerable development |
| Low | Lower quality | Surface water | Watercourses not having a WFD classification shown in a RBMP and $Q_{95}$ ≤0.001m$^3$/s |
| | | Groundwater | Unproductive strata |
| | | Flood risk | Water compatible development |

### Magnitude of impacts

13.4.11 The approach used to assess magnitude of impacts on water environment features considers the change to the receptor. This considers the severity of impact of the scheme, together with the vulnerability of the receptor to change.

13.4.12 Table 13-4 summarises the potential magnitude of any construction or operation impact on the receptor, as per Table 3.71 of LA 113.

**Table 13-4 Estimating the magnitude of an impact on an attribute**

| Magnitude | Criteria | Attribute | |
|---|---|---|---|
| Major adverse | Results in loss of attribute and/or quality and integrity of the attribute | Surface water | Failure of both acute-soluble and chronic-sediment related pollutants in Highways England's Water Risk Assessment Tool (HEWRAT) and compliance failure with Environmental Quality Standards (EQS) values<br>Calculated risk of pollution from a spillage ≥2% annually (spillage assessment)<br>Loss or extensive change to a fishery<br>Loss of regionally important public water supply<br>Loss or extensive change to a designated nature conservation site<br>Reduction in water body WFD classification |
| | | Groundwater | Loss of, or extensive change to, an aquifer<br>Loss of regionally important water supply<br>Potential high risk of pollution to groundwater from routine runoff – risk score >250 (Groundwater quality and runoff assessment)<br>Calculated risk of pollution from spillages ≥2% annually (spillage assessment)<br>Loss of, or extensive change to GWDTE or baseflow contribution to protected surface water bodies<br>Reduction in water body WFD classification<br>Loss or significant damage to major structures through subsidence or similar effects |
| | | Flood risk | Increase in peak flood level (>100mm) |

| Magnitude | Criteria | Attribute | |
|---|---|---|---|
| Moderate adverse | Results in effect on integrity of attribute, or loss of part of attribute | Surface water | Failure of both acute-soluble and chronic-sediment related pollutants in HEWRAT but compliance with EQS values<br>Calculated risk of pollution from spillages ≥1% annually and <2 % annually<br>Partial loss in productivity of a fishery<br>Degradation of regionally important public water supply or loss of major commercial/industrial/agricultural supplies<br>Contribution to reduction in water body WFD classification |
| | | Groundwater | Partial loss or change to an aquifer<br>Degradation of regionally important public water supply or loss of significant commercial/industrial/agricultural supplies<br>Potential medium risk of pollution to groundwater from routine runoff – risk score 150-250<br>Calculated risk of pollution from spillages ≥1% annually and <2 % annually<br>Partial loss of the integrity of GWDTE<br>Contribution to reduction in water body WFD classification<br>Damage to major structures through subsidence or similar effects or loss of minor structures |
| | | Flood risk | Increase in peak flood level (>50mm) |
| Minor adverse | Results in some measurable change in attributes, quality or vulnerability | Surface water | Failure of either acute soluble or chronic sediment related pollutants in HEWRAT<br>Calculated risk of pollution from spillages ≥0.5% annually and < 1% annually<br>Minor effects on water supplies |
| | | Groundwater | Potential low risk of pollution to groundwater from routine runoff – risk score <150<br>Calculated risk of pollution from spillages ≥0.5% annually and <1%annually<br>Minor effects on an aquifer, GWDTEs, abstractions and structures |
| | | Flood risk | Increase in peak flood level (>10mm) |
| Negligible | Results in effect on attribute, but of insufficient magnitude to affect the use or integrity | The proposed project is unlikely to affect the integrity of the water environment. | |
| | | Surface water | No risk identified by HEWRAT (pass both acute-soluble and chronic-sediment related pollutants)<br>Risk of pollution from spillages <0.5% |
| | | Groundwater | No measurable impact upon an aquifer and/or groundwater receptors and risk of pollution from spillages <0.5% |
| | | Flood risk | Negligible change to peak flood level (≤ +/- 10mm) |

| Magnitude | Criteria | Attribute | |
|---|---|---|---|
| Minor beneficial | Results in some beneficial effect on attribute or a reduced risk of negative effect occurring | Surface water | HEWRAT assessment of either acute soluble or chronic-sediment related pollutants becomes pass from an existing site where the baseline was of 'fail' condition<br>Calculated reduction in existing spillage risk by 50% or more (when existing spillage risk is <1% annually) |
| | | Groundwater | Calculated reduction in existing spillage risk by 50% or more to an aquifer (when existing spillage risk <1% annually)<br>Reduction of groundwater hazards to existing structures<br>Reductions in waterlogging and groundwater flooding |
| | | Flood risk | Creation of flood storage and decrease in peak flood level (>10mm) |
| Moderate beneficial | Results in moderate improvement of attribute quality | Surface water | HEWRAT assessment of both acute-soluble and chronic-sediment related pollutants becomes pass from an existing site where the baseline was of 'fail' condition<br>Calculated reduction in existing spillage by 50% or more (when existing spillage risk >1% annually)<br>Contribution to improvement in water body WFD classification |
| | | Groundwater | Calculated reduction in existing spillage risk by 50% or more (when existing spillage risk is >1% annually)<br>Contribution to improvement in water body WFD classification<br>Improvement in water body CAMS (or equivalent) classification<br>Support to significant improvements in damaged GWDTE |
| | | Flood risk | Creation of flood storage and decrease in peak flood level1 (>50mm) |
| Major beneficial | Results in major improvement of attribute quality | Surface water | Removal of existing polluting discharge or removing the likelihood of polluting discharges occurring to a watercourse. Improvement in water body WFD classification |
| | | Groundwater | Removal of existing polluting discharge to an aquifer or removing the likelihood of polluting discharges occurring<br>Recharge of an aquifer. Improvement in water body WFD classification |
| | | Flood risk | Creation of flood storage and decrease in peak flood level (>100mm) |
| No change | | No loss or alteration of characteristics, features or elements; no observable impact in either direction | |

### Significance of effect

13.4.13 By combining the magnitude of impact (or change) and the value of each water environment feature, an assessment has been made of the significance of effect, considering the possibility and nature of mitigation. The resultant effects may be either negative (adverse), positive (beneficial) or neutral, depending on the nature of the impact.

13.4.14 In accordance with Table 3.8.1 of LA 104, the significance of effect upon the receptor is assessed using the matrix in Table 13-5. Effects are defined on a nine-point scale (very large beneficial, large beneficial, moderate beneficial, slight beneficial, neutral, slight adverse, moderate adverse, large adverse or very large adverse).

13.4.15 Where the matrix suggests more than one likely outcome, for instance slight or moderate, professional judgement has been used in conjunction with the descriptors in Table 13-5 to arrive at a robust conclusion.

**Table 13-5 Significance matrix (taken from Table 3.8.1 of LA 104)**

| | | 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 |

13.4.16 Effects of moderate significance represent a significant effect. Moderate adverse effects represent a significant effect that require mitigation, and function as means for the decision maker to take account of the likely significant effects of the scheme.

### Construction impacts

13.4.17 LA 113 recommends that an assessment of construction impacts should use the advice given in CIRIA Report C648 Control of Water Pollution from Linear Construction Projects[4] on potential impacts arising during the construction phase and the assessment and mitigation of these risks.

13.4.18 The potential impacts of construction on surface water or sediment runoff, water quality, flood risk and groundwater quality or level have been assessed based on standard construction methods and sequencing, including the EA's Pollution Prevention Guidelines (PPGs) (withdrawn in 2015), and their replacement series – Guidance for Pollution Prevention (GPPs), and the relevant CIRIA publications. Cumulative impacts as a result of construction phasing have also been assessed.

13.4.19 Outline measures to reduce construction impacts are included in Annex G Ground and surface water management plan of ES Appendix 2.1 Environmental Management Plan (EMP) (Document Reference 6.4). These measures would be secured by a requirement of the DCO. These measures are also reported in the Register of Environmental Actions and Commitments in ES Appendix 2.1 EMP (Document Reference 6.4).

13.4.20 The potential impacts of construction on hydrogeology have been evaluated within ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4), by consideration of the proposed construction activities in the context of a baseline conceptual model of the hydrogeological regime. The methodology for groundwater assessment incorporates the Environment Agency (EA) guidance for Dewatering Abstractions (SC040020 SR1[5] and SR2[6]).

**Operational impacts**

13.4.21 All assessments follow a source – pathway – receptor approach, by which for there to be a risk of impact to surface water or groundwater, a source, pathway and receptor all have to be present to create a pollutant linkage or create a linkage based on natural processes. In the context of this chapter, pollutant sources comprise pollution sources associated with the construction and operation of the scheme, and the receptors are the receiving water environment, including surface water, groundwater and springs.

<u>WFD compliance assessment</u>

13.4.22 A WFD compliance assessment for the scheme has been conducted (ES Appendix 13.2 WFD Compliance Assessment (Document Reference 6.4)), with reference to the Planning Inspectorate (PINS) Advice Note 18 The Water Framework Directive[7].

13.4.23 The WFD quality and quantity elements identified through scoping as being at potential risk of impact from the scheme have been assessed in the WFD compliance assessment.

13.4.24 The WFD assessment identifies how the scheme has the potential to affect each of the water body's quality/quantity elements and if this results in non-compliance with the WFD. The results of the other assessments in this chapter are used to inform the WFD assessment, where considered applicable.

13.4.25 For water bodies that have the potential to be impacted by the scheme, the effect of the scheme on any mitigation measures identified within the relevant RBMP has been assessed.

<u>Flood risk</u>

13.4.26 A flood risk assessment (FRA) for the scheme has been conducted and is provided in ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4)).

13.4.27 This includes the details of the methodology used to assess the risk of flooding from pluvial, fluvial and groundwater sources as a result of the scheme. This follows an approach agreed with Highways England (as the Highway Authority), Gloucestershire County Council (GCC) (as the Lead Local Flood Authority (LLFA)) and the EA (as Lead Authority for main rivers).

13.4.28 The FRA uses 40% uplift to peak rainfall as its climate change allowance, as the modelled area is considered to be a small catchment area (less than $3km^2$)[8].

Routine runoff and surface water quality

13.4.29 A simple assessment (as defined in section 13.4.5) of the potential impacts of routine runoff on surface water quality has been undertaken using the Highways England Water Risk Assessment Tool (HEWRAT) to determine whether the risk is acceptable (see ES Appendix 13.4 Water quality assessment (Document Reference 6.4)).

13.4.30 The assessment has been conducted at locations where the route physically interacts with watercourses (for example culverts or realignments) or where sediment loading from the drainage system may occur.

13.4.31 The modelling of the surface waters includes:

- MicroDrainage hydrologic modelling – to understand surface water flow paths, provide a measure of pipe size and attenuation.
- Modelling of the rainfall return period events with allowance for climate change.

13.4.32 These models have been used to design suitable drainage systems and mitigation measures, including the design of channel diversions.

Groundwater quality and routine runoff

13.4.33 A simple assessment (as defined in section 13.4.5) of groundwater quality and routine runoff has been undertaken (see ES Appendix 13.4 Water Quality Assessment (Volume 6 Document Reference 6.4)). This uses Appendix C *Groundwater quality and run off* of LA 113, which provides a methodology to determine the risk of impact on groundwater quality from routine runoff. For there to be a risk of impact to groundwater quality, a source, pathway and receptor all have to be present to create a pollutant linkage or create a linkage based on natural processes.

Hydromorphological assessment

13.4.34 A simple hydromorphological assessment (as defined in section 13.4.5) has been undertaken to determine the potential impacts upon hydromorphology (see ES Appendix 13.5 Hydromorphology Assessment (Document Reference 6.4)).

13.4.35 The appropriate methods of assessment to measure hydromorphological change have been determined by a competent expert on a site-specific basis. Appendix E Hydromorphological assessment of LA 113 has been followed.

13.4.36 A qualitative assessment, including River Habitat Surveys and fluvial audits, of possible impacts on the hydromorphology of watercourses has been undertaken based on a suitably qualified geomorphologist's understanding of the potential for impacts to the flow dynamics and sediment transport processes and the subsequent effects that this might have on the ecological potential of the water feature.

13.4.37 The assessment has been made using professional judgement and experience of working within similar watercourses and is focussed on locations where the scheme physically interacts with watercourses (for example culverts or realignments) or where sediment loading from the drainage system may occur.

Accidental spillage

13.4.38 An accidental spillage assessment has been undertaken using Appendix D Spillage assessment from LA 113 (see ES Appendix 13.6 Spillage Risk

Assessment (Document Reference 6.4)). Using the spillage assessment method, for the risk of a serious pollution incident to be acceptable the calculated annual probability of such an incident shall not be greater than 1%. Where spillage has the potential to affect a SSSI, SPZ, protected area, drinking water supply or commercial activity abstracting from the watercourse, for the risk of a serious pollution incident to be acceptable the calculated annual probability shall not be greater than 0.5%.

Groundwater

13.4.39 An assessment has been undertaken following the procedures set out in Appendix A Groundwater levels and flow of LA 113. This follows a stepped approach.

- Step 1 – Establish regional groundwater body status.
- Step 2 – Develop a conceptual model for the surrounding area.
- Step 3 – Based on the conceptual model, identify all potential features which are susceptible to groundwater level and flow impacts.

13.4.40 The assessment of potential effects resulting from the scheme construction and operation considers the interaction of the baseline conditions presented in the Hydrogeological Impact Assessment in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4) with the scheme, particularly focusing on the following specific elements of the scheme (detailed in ES Chapter 2 The project (Document Reference 6.2)):

- Earth bunding (Ch. 0+900 to Ch. 1+700) and the tributary of Norman's Brook diversion in on-line section.
- Ground stabilisation measures along the on-line section.
- Cutting (Ch. 1+700 to Ch. 3+000) spanning over on-line and off-line sections.
- Structures (including the Cotswolds Way crossing, Gloucestershire Way crossing, Cowley overbridge and Stockwell overbridge).
- Embankments at Shab Hill junction (Ch. 3+200) in off-line section.
- Cuttings between Shab Hill junction and Cowley junction (Ch. 3+200 to Ch. 5+000) in the off-line section.

13.4.41 Information from the water features survey in ES Appendix 13.11 Water Features Survey (Document Reference 6.4) has been incorporated into a conceptual model of the scheme to identify key features that pose a risk to groundwater resources.

13.4.42 The Hydrogeological Impact Assessment has been prepared to evaluate the quantitative impacts of the scheme on selected groundwater receptors before and after mitigation. It was conducted in accordance with LA 113 and EA guidance for dewatering abstractions (SC040020/SR1) and groundwater abstractions (SC040020/SR2).

13.4.43 The source-pathway-receptor model has been applied to water resources and water features that are sensitive to groundwater levels and flow. In this context sources include abstraction and recharge points, which may be for dewatering or drainage purposes, that are artificially altering groundwater level and flows. The pathway is the hydraulic connection between the water resource that is being changed and features up or down gradient, so this could include the aquifer that connects the two. The receptors are groundwater bodies and groundwater-dependent features.

Groundwater-dependent terrestrial ecosystems (GWDTEs)

13.4.44 A simple assessment (as defined in section 13.4.5) has been undertaken following the procedures set out in Appendix B Groundwater-dependent terrestrial ecosystems of LA 113, which follows a stepped, risk-based approach which depends upon establishing linkages between potential impacts from the scheme on the hydrological and hydrogeological regime and the GWDTEs.

13.4.45 The site-specific conceptual hydrogeological model provides an overview of the interactions between groundwater and surface water and identifies potential linkages between potential impacts from the scheme (during construction or operation) and GWDTEs. Groundwater flow paths, groundwater levels and the proximity of GWDTEs have been taken into account in the conceptual hydrogeological model, included in the ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

**Consultation**

13.4.46 A number of stakeholders have been consulted to gather baseline data and inform the assessment. The consultees and the reasons for consultation with them (specific to this chapter) are described in the following sections.

13.4.47 A Scoping Opinion was provided by PINS (see ES Appendix 4.1 The Planning Inspectorate Scoping Opinion (Document Reference 6.4), which included responses relating to road drainage and the water environment from the EA, Cotswold Conservation Board (CCB), Cowley and Birdlip Parish Council and GCC. These responses have been considered and included, where appropriate, in this chapter and are detailed in ES Appendix 4.2 Responses to Scoping Opinion (Document Ref 6.4).

13.4.48 The EA has been consulted on the scope of the monitoring to be undertaken, as well as key effects of the scheme and mitigation. The EA would be consulted on future risk assessments for activities that may impede groundwater flow and quality, via the construction of impermeable barriers, and activities such as piling, ground improvement works and foundations, as per their request.

13.4.49 It has been acknowledged by the EA that full numerical modelling of the groundwater system is beyond the scope of this assessment given the complexities of the hydrogeological regime in the study area. ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4) has instead focussed on developing conceptual models around selected design elements of the scheme to understand the hydrogeological regime, following the methodology set out in Appendix A Groundwater levels and flow of LA 113.

13.4.50 GCC, Stroud District Council and Cotswold District Council were consulted during Option Selection (2018) to obtain baseline data including local and unlicensed abstractions. Details on Option Selection (2018) is provided in ES Chapter 3 Assessment of alternatives (Document Reference 6.2).

13.4.51 GCC has been consulted in their capacity as the LLFA with regards to the assessment of flood risk, crossing of ordinary watercourses and road drainage.

13.4.52 Thames Water and Severn Trent Water were consulted during the development of the ES regarding the locations of water and wastewater utilities.

13.4.53 The record of consultation with the EA, GCC and Joint Councils is recorded in the respective Statement of Common Ground, see Statement of Commonality (Document Reference 7.3).

## 13.5 Assessment assumptions and limitations

13.5.1 Assessment of the road drainage and the water environment aspects of the scheme has been undertaken in accordance with LA 113, and supplementary methods (as explained in section 13.4) for potential impacts not covered in LA 113.

13.5.2 For the assessment of construction impacts, where construction methods and sequencing are not available, current standard construction practices are based on the EA's PPGs (withdrawn in 2015), subsequent guidance on GOV.UK, the relevant CIRIA publications and best practice measures outlined in the GPPs.

13.5.3 The baseline conditions have been derived from both desk-based and field studies, and data updated based upon latest findings from direct observations and sampling. This has included information obtained from water features surveys (ES Appendix 13.11 Water features survey (Document Reference 6.4)), intrusive ground investigations and groundwater monitoring (see section 13.7.12 and onwards), water environment monitoring (ES Appendix 13.12 Water features survey (Document Reference 6.4)), revising the surface water catchments within the study area following tracer testing (see section 13.7.25) and detailed investigations (ES Appendix 13.10 Drainage Report (Document Reference 6.4)).

13.5.4 It is acknowledged that uncertainty is inherent to the assessment of interaction between surface water and groundwater. However, the collected data have enhanced the understanding of current and future conditions and are reported in the ES.

13.5.5 Every effort has been made to ensure that the findings of the available surveys present as accurate an interpretation as possible of the baseline conceptual model of the water environment within the study area.

13.5.6 This chapter includes the information reasonably required to assess potential environmental effects. The assessments represent a 'reasonable worst-case' and are based on conservative inputs derived from available field or desk study data and published research literature relevant to the study area.

13.5.7 The findings presented in this chapter are based upon the data available at the time of writing including data collected to end of October 2020 for groundwater and December 2020 for surface water and springs. Any data collected following these dates would be used to refine the conceptual models to support the detailed design phase and would form part of the ongoing dialogue with the EA and others.

13.5.8 Further topic-specific limitations and assumptions associated with the assessment of effects within this chapter are discussed in the following sections.

### Surface water

13.5.9 For the HEWRAT model, flow data is required. Catchment descriptors were obtained from the Flood Estimation Handbook (FEH) Web Service and $Q_{95}$ (flow in cubic metres per second which equals or exceeds 95% of the flow record) subsequently derived using the FEH LowFlows tool, the standard method for estimating $Q_{95}$ in the absence of monitoring data. The estimated values have been confirmed through direct observation via site walkover and spot flow measurement. All receiving watercourses are headwater streams with low estimated $Q_{95}$ values, ranging from <0.001 to 0.002 $m^3/s$.

13.5.10 The water hardness parameter for HEWRAT was obtained from the Drinking Water Inspectorate Map for England and Wales which shows the rate of water hardness. This data was considered to be appropriate to use in the absence of chemical data for each watercourse when the HEWRAT analysis was undertaken. This assumption has been validated by baseline water quality monitoring. It is assumed that local potable water would have a similar hardness characteristic as the local surface water and the three water hardness levels used by the HEWRAT model are based on broad ranges.

13.5.11 Nine months of surface water quality and flow data, between August 2020 and April 2021, have been collected and are presented in ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4). The locations are shown on ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3). The overall duration of the monitoring will be twelve months to capture a range of hydrological events.

**Groundwater**

13.5.12 It has been acknowledged by the EA that full numerical modelling of the groundwater system is beyond the scope of this assessment. This is due to the complexities of the hydrogeological regime in the study area, which cannot be defined in a three-dimensional numerical model sufficiently enough to accurately represent the processes occurring within the study area and how they may be affected by the scheme. Therefore, analytical and two-dimensional conceptual models have been developed for key assessment areas, which have been tailored for structural and geotechnical design assessments, following the methodology set out in Appendix A Groundwater levels and flow of LA 113. This approach has met with the EA's approval during the scheme consultations.

13.5.13 The intrusive ground investigations field work to determine the site-specific ground conditions across the majority of the scheme have now been completed and groundwater monitoring is currently ongoing, due for completion by end of June 2021. These are described in section 13.7 Baseline conditions. This is with an exception of scheme section approximately Ch. 2+100 to 2+600, where no land access was granted at the time of the field works. Ground investigations commenced in February 2021 and were completed in March 2021. Subsequent groundwater monitoring will continue until March 2022. Information obtained from these investigations will be considered at detailed design. Based on the hydrogeological conceptual model derived for the scheme informed by groundwater monitoring data obtained from scheme sections located on either end of the non-investigated section, the scheme would not intercept groundwater as the groundwater table is at least 30m below the scheme. Therefore, the available information on groundwater levels is considered sufficient to inform the assessments.

13.5.14 No groundwater monitoring was completed along the scheme alignment Ch. 0+000 to approximately Ch. 0+500. The scheme does not require significant excavations in this section because it runs either at grade or on an embankment largely within the footprint of the existing dual carriageway A417. As the scheme poses a low risk to water environment it was considered unnecessary to investigate this section in order to complete robust assessments.

13.5.15 Conceptual models applied within the assessment have been derived with the baseline groundwater level monitoring information received up to the end of October 2020 to inform the hydrogeological impact assessments in the ES. For the majority of the completed monitoring locations at least 11-12 months of monitoring data is available. This provides data on seasonal variations of groundwater regime, as requested and agreed with the EA through the consultations. Therefore, this data is considered sufficient to complete the assessments. Data obtained from scheme section approximately Ch. 2+100 to 2+600 and groundwater monitoring data post October 2020 would be considered at detailed design to refine the conceptual models.

13.5.16 Nine months of spring water quality and flow data, between August 2020 and April 2021, have been collected and are presented in ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4). The locations are shown on ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3). The overall duration of the monitoring will be 12 months to capture a range of hydrological events.

**Limits of deviation (LoD)**

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

13.5.18 The vertical and lateral LoD for the scheme have been reviewed with respect to identified sensitive receptors, particularly considering potential impacts on conclusions of quantitative hydrogeological impact assessments and potential impacts as a result of an extended footprint of the scheme. The vertical and lateral LoD are not considered to significantly affect the conclusions of the assessments.

## 13.6 Study area

13.6.1 The study area is based on the 'source-pathway-receptor' pollutant linkage principle and is shown on ES Figure 13.1 Surface water features (Document Reference 6.3).

13.6.2 For direct effects on surface waters, the study area includes the geographical extent of the full scope of the works and all surface water features within 0.6 miles (1 kilometre), where features have hydrological connectivity to the scheme.

13.6.3 For groundwater, the study area includes the geographical extent of the full scope of the works and all groundwater features within 1 kilometre of the scheme.

13.6.4 The PINS Scoping Opinion (ES Appendix 4.1 The Planning Inspectorate Scoping Opinion (Document Reference 6.4)) and meetings with the EA highlighted the need to extend the study area beyond 0.6 miles (1 kilometre). Extension of the study area was considered necessary by the EA to capture potential impacts to receptors beyond the originally proposed study area. This was considered particularly important where dewatering would be likely to impact receptors upstream and downstream of the study area where underlying geology may result in groundwater connectivity across a wider area.

13.6.5 Consequently, a risk-based approach has been taken to the extension of the study area based on assessment of impact pathways and has been kept under review as the understanding of complex interactions has evolved. Following review, tributaries to the River Churn and the headwaters to the River Churn, up to 1.1 miles (1.8 kilometres) north of the scheme, were included in the study area due to their local significance.

13.6.6 The hydrogeological study area is shown on ES Figure 13.5 Hydrogeological study area and features (Document Reference 6.3).

## 13.7 Baseline conditions

### Baseline methodology

13.7.1 The baseline describes the existing condition of surface waters, groundwater and flood risk within the study area. The value of each water feature identified has been determined based on the attributes and indicators of quality listed in Table 3.69 of LA 113 and shown in Table 13-3.

13.7.2 The following data sources were used to compile the baseline conditions:

- Observations from site walkover surveys.
- Observations from water features survey (March 2018 to April 2019) within ES Appendix 13.11 Water Features Survey (Document Reference 6.4).
- EA Catchment Data Explorer, including relevant information from the Severn and Thames River Basin Management Plans 2015[9].
- Existing highway drainage plans (ES Figure 13.18 Existing Highway Drainage Plan (Document Reference 6.3)).
- National River Flow Archive[10].
- Natural England, Multi-Agency Geographic Information for the Countryside (MAGIC)[11].
- Ordnance Survey (OS) mapping (including topography).
- British Geological Survey (BGS) mapping[12].
- EA flood risk mapping[13].
- EA Water Quality Archive[14].
- Topographic surveys.
- Highways England's Drainage Data Management System (HADDMS)[15].
- ES Appendix 8.3 National Vegetation Classification (NVC) woodland report (Document Reference 6.4).
- ES Appendix 9.4 Groundsure Enviro Insight Report (Document Reference 6.4).

13.7.3 Further to the list above, the following also provide baseline information as part of the suite of appendices supporting this ES chapter.

- Information from historic and recent ground investigations including:
  - Surface water flow and quality monitoring (ES Appendix 13.12 Water environment monitoring data (Document Reference 6.4)).
  - Spring water flow and quality monitoring (ES Appendix 13.12 Water environment monitoring data (Document Reference 6.4)).
  - Groundwater level and quality monitoring (ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4)).
  - Permeability testing (factual data is presented in ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4)).
- ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4) (Flood Risk Assessment of the tributary of Norman's Brook).
- Preliminary Groundwater Report[16].

- ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).
- ES Appendix 13.11 Water Features Survey (Document Reference 6.4).
- ES Appendix 13.12 Water environment monitoring data (Document Reference 6.4).

**Site investigations and surveys**

13.7.4 Several site investigations and surveys have been completed for the scheme including walkover surveys, a survey of water features, geotechnical ground investigation and a surface water tracer test.

Water features survey

13.7.5 A water features survey was completed between April 2018 and March 2019, which included five rounds of surveys. The surveys were conducted within the study area and at some locations beyond the study area, as the survey area was developed prior to option 30 becoming the preferred alignment. Locations outside the study area were identified due to their potential hydraulic connectivity to features within the study area that may be impacted.

13.7.6 Three hundred and ten surface water and groundwater features were surveyed, including, but not limited to, watercourses, groundwater springs, wet flushes (boggy ground), seepages, road drainage pipes, ponds and groundwater abstractions. Most locations were only visited once during the survey period. Forty-five sites were selected for flow gauge monitoring of watercourses including some groundwater springs, with the majority of these features being gauged twice.

13.7.7 The water features within the study area demonstrate that a number of surface water features rely on groundwater sources from the Great Oolite Group and Inferior Oolite Group aquifers, superficial and perched aquifers and their separation with less permeable Lias Group mudstones and the Fullers Earth Formation mudstone.

13.7.8 Spring discharges, wet flushes (boggy ground) and seepages, were mainly found on the escarpment slope but also within the Upper Cotswold Plateau valleys where some valleys are seasonally dry and others have perennial and ephemeral spring flows which can also support wetland environments, including Bushley Muzzard SSSI. This SSSI is an area of marshland that has the potential to be impacted by changes in groundwater levels/quality and drainage related to the scheme.

13.7.9 Details of the water features survey are presented in ES Appendix 13.11 Water Features Survey (Document Reference 6.4).

Walkover surveys

13.7.10 Walkover surveys of the study area were undertaken on 11 June 2019, 28 June 2019, 6 August 2019, 8 August 2019, 28 October 2019, 29 October 2019 and 8 December 2020. The visits focused on building on information from the water features survey (see ES Appendix 13.11 Water Features Survey (Document Reference 6.4)) to gain a good overall understanding of the hydrological and hydrogeological regime of the study area.

13.7.11 The weather conditions for the visits varied and seasonal changes in the water environment were evident. Summer visits showed springs generally producing low volumes of water, resulting in watercourses having low flow and levels, and winter visits showed springs producing higher volumes of water resulting in watercourses having higher levels and flows.

Ground investigations

13.7.12 Details regarding historical ground investigations are included in ES Chapter 9 Geology and soils (Document Reference 6.2). Although information obtained through these investigations has been used to inform the conceptual ground model for the scheme, these investigations primarily focused on geotechnical aspects.

13.7.13 Recent ground investigations and monitoring were specific to the scheme. The details are presented in ES Chapter 9 Geology and soils (Document Reference 6.2). The following sections provide a summary of hydrogeological aspects of these investigations.

Phase 1 Ground Investigation 2019

13.7.14 The Phase 1 ground investigation was completed between January and February 2019 (ES Appendix 9.3 Ground investigation factual repot (Document Reference 6.4)). The scope of works included eight boreholes with standpipe installations in each specifically targeting key hydrogeological elements to support the conceptual model of the scheme options. Groundwater level data loggers were installed in three locations: DS/RC 406, DS/RC 408 and DS/RC 419. To compensate for the total pressure recorded by the water level loggers for barometric pressure, a dedicated barometric logger was installed in the headworks of DS/RC 408. The locations are shown on ES Figure 13.9 Groundwater monitoring locations (Document Reference 6.3).

13.7.15 The boreholes were positioned in four locations, where at each location two boreholes were drilled approximately 10m apart, monitoring different aquifer units in relation to the geological faulting. Groundwater monitoring commenced on completion of the installations, between January and February 2019. Groundwater level monitoring using data loggers commenced in March 2019 and the data gathering is currently on-going and is programmed to be completed in mid-2021. Selected boreholes will continue to be monitored until construction commences. The collected data will form the basis of the pre-construction baseline. A summary of the Phase 1 ground investigation monitoring results to date is presented in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

13.7.16 Permeability testing was completed in seven installations. The results are summarised in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

Phase 2A Ground Investigations 2019 – 2020

13.7.17 The Phase 2A ground investigations commenced in March 2019 and were completed in October 2020 with the post-field works 12 months monitoring programmed to be completed in August 2021 (ES Appendix 9.3 Ground investigation factual repot (Document Reference 6.4)).

13.7.18 The initial scope of Phase 2A included 80 boreholes, however due to land access issues ten boreholes were not completed at the time of assessment (refer to section 13.5 Assessment assumptions and limitations). Of the 70 completed boreholes, 52 groundwater monitoring installations were constructed and 14 of these locations include water level loggers. Ten out of 11 scheduled boreholes specifically targeting key hydrogeological elements to support the conceptual model of the scheme (so called 'series 400') have been completed. The locations are shown on ES Figure 13.9 Groundwater monitoring locations (Document Reference 6.3).

13.7.19 The final ten boreholes were drilled in February and March 2021 and will provide groundwater monitoring until March 2022.

13.7.20 All of the completed boreholes are targeting a specific aspect of the design. Barometric loggers have been installed at Crickley Hill in the headworks of CP 223 and at Stockwell-Nettleton Bottom in the headworks of DS/RC 220.

13.7.21 Groundwater level monitoring commenced on completion of each installation and is on-going with completion expected in mid-2021. Selected boreholes will continue to be monitored until construction commences. The collected data will form the basis of the pre-construction baseline. A summary of the Phase 2A ground investigation monitoring results is presented in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

13.7.22 The Phase 2A scope included nine packer tests. No packer tests have been completed due to insufficient depth of the saturated zone. Instead, variable head testing has been undertaken in seven installations. The results are presented in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

13.7.23 The baseline conditions underpinning the hydrogeological impacts assessment consider data collected until end of October 2020 comprising:

- 21 months of groundwater monitoring data from the Phase 1 boreholes, where monitoring commenced in February 2019.
- 10-13 months of data from the Phase 2A boreholes (series 400), the majority of which were installed between September and December 2019.
- 6-21 months of data from Phase 2A boreholes (other than series 400 boreholes equipped with installations).

13.7.24 The length of monitoring period during the Phase 2A investigations is dependent on installation date. The longest monitoring periods are from areas in the western end of the scheme, from the early stages of the investigation.

<u>Tracer test</u>

13.7.25 A tracer test was conducted using tracer dye on 6 March 2019 on the watercourse located along the southern toe of Crickley Hill, below the existing road. The test was completed to ascertain where the watercourse flowed to. The tracer confirmed that the tributary is hydraulically connected to Norman's Brook via a culvert network, rather than to Horsbere Brook as indicated in WFD water body delineation. Results are shown in ES Appendix 13.11 Water Features Survey (Document Reference 6.4).

Water environment monitoring

13.7.26 As outlined in section 13.5 Assessment assumptions and limitations, rainfall monitoring and monitoring of flow and water quality of surface water and spring receptors and rainfall is being undertaken to inform the design and construction of the scheme, and is reported on in the chapter and its appendices. The aim of the monitoring is to provide an understanding of the hydrological processes and system within the study area by monitoring the chosen locations over a 12-month period to capture a range of hydrological events.

*Surface water*

13.7.27 Six surface water flow locations are being monitored, of which there are three continuous (gauged) sites and all locations had spot (monthly) measurements.

13.7.28 Six surface water quality sampling locations have been identified for ongoing monitoring. Parameters sampled include environmental indicators to identify the specific local characteristics of the water and pollutants typically associated with road runoff.

13.7.29 Nine months of surface water quality and flow data, between August 2020 and April 2021, have been collected and is presented in ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4) with details of methodology and parameters being monitored. The overall duration of the monitoring would be 12 months to capture a range of hydrological events.

13.7.30 The monitoring locations are shown on ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3).

*Springs*

13.7.31 Seven spring flow locations are being monitored. These are all spot (monthly) measurements.

13.7.32 Seven spring water quality sampling locations have been identified for ongoing monitoring. Parameters sampled include environmental indicators to identify the specific local characteristics of the water and pollutants typically associated with road runoff.

13.7.33 Nine months of spring quality and flow data, between August 2020 and April 2021, have been collected and are presented in ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4). The overall duration of the monitoring would be 12 months to capture a range of hydrological events.

13.7.34 The locations are shown on ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3).

*Rainfall*

13.7.35 Site-specific rainfall gauges were installed at two locations in September and October 2020.

13.7.36 Both locations are shown on ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3) and the methodology and results are presented in ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4). The overall duration of the monitoring will be 12 months to capture a range of hydrological events.

### Designated sites

13.7.37 Bushley Muzzard SSSI is a species-rich wet grassland supplied by local springs and seepages[17]. It is located downgradient of the southern end of the Existing A417 roundabout, south of Birdlip Quarry. As detailed in ES Appendix 13.8 Groundwater dependant terrestrial ecosystems assessment (Document Reference 6.4), Bushley Muzzard SSSI supports a habitat community that has the potential to be dependent on groundwater. The SSSI is within a valley feature adjacent to the contact between the Great Oolite Group over the Fuller's Earth Formation. Consequently, there are springs associated with the geological contact in this area that contribute to the marshland conditions of the SSSI. These springs support fen-meadow (M22) vegetation, which may be sensitive to changes in local groundwater condition[18].

13.7.38 Crickley Hill and Barrow Wake SSSI is designated for calcareous grassland habitats, broadleaved woodland (including beech woodland) and nationally important rock exposures[19]. It is located adjacent to the Existing A417 on Crickley Hill and at Barrow Wake. Springs supplying the tributary of Norman's Brook are outside the protected area downgradient and south of Barrow Wake. The NVC code for beech trees (*Fagus sylvatica*) is 'W12', which is not classified as being groundwater-dependant according to relevant guidance[20]. The ecological surveys completed for the scheme did not identify the presence of potentially-groundwater-dependent habitats[21].

13.7.39 Cotswold Commons and Beechwoods SSSI and Cotswold Beechwoods SAC, located to the west and downslope of the B4070. As mentioned above the beech woodland is not classified as a groundwater-dependent habitat, however these designated sites include areas of vegetation are associated with some nationally rare invertebrate species. These protected areas extend from the south-east of Birdlip to High Brotheridge and include springs supplying Horsbere Brook.

13.7.40 Witcombe Reservoirs, at the foot of the escarpment, is primarily supplied by spring-fed watercourses. It discharges to Horsbere Brook. There are a number of small ponds in the area that may be partially groundwater-dependent or fed by springs.

13.7.41 Associated ecology baseline of the groundwater-dependent habitats is considered in ES Chapter 8 Biodiversity (Document Reference 6.2).

### Surface water

13.7.42 The Cotswold escarpment forms a surface water divide between the River Severn catchment and the River Thames catchment. To the west of the divide, the land drains to the River Severn and its tributaries, including Norman's Brook (via the tributary of Norman's Brook), Horsbere Brook and the River Frome. To the east and south-east, the land drains to the River Churn, a tributary of the Thames, via unnamed tributaries.

13.7.43 Horsbere Brook, Norman's Brook, the River Frome and the River Churn are classed by the EA as ordinary watercourses within the study area and are shown on ES Figure 13.1 Surface water features (Document Reference 6.3). Minor watercourses that are tributaries of these named streams have also been included in the assessment and grouped where required.

13.7.44 Headwaters of several watercourses in the study area, such as tributary of Norman's Brook, an unnamed tributary of the River Frome and two unnamed tributaries of the River Churn are fed by springs. Some of these streams have losing and gaining reaches meaning that stream flow can be seasonal. As a result, these surface water courses are dependent on groundwater and sensitive to changes in groundwater levels and flows.

13.7.45 Details on the springs feeding the watercourses are provided in Table 13-13.

Surface water WFD catchments

13.7.46 The EA's Catchment Data Explorer and ES Figure 13.3 WFD surface waterbodies (Document Reference 6.3) show that the WFD surface water bodies in the Severn Vale Management Catchment include:

- Norman's Brook – source to confluence Hatherley Brook (No. GB109054032780), within the Cheltenham Hatherley and Norman's Brook Operational Catchment.
- Horsbere Brook – source to confluence River Severn (No. GB109054032760), within the Gloucester Tributary Operational Catchment.
- River Frome – source to Ebley Mill (No. GB109054032470), within the Frome and Cam Operational Catchment.

13.7.47 The WFD surface water body in the Gloucestershire and the Vale Management Catchment is the Churn – source to Perrots Brook (No. GB106039029810), within the Thames Upper Operational Catchment.

13.7.48 The 2019 status for these surface water bodies are as follows:

- Norman's Brook – source to confluence Hatherley Brook: Ecological status of 'Moderate', chemical status of 'Fail', and overall status of 'Poor'.
- Horsbere Brook – source to confluence River Severn: Ecological status of 'Moderate', chemical status of 'Fail', and overall status of 'Moderate'.
- River Frome – source to Ebley Mill: Ecological status of 'Good', chemical status of 'Fail', and overall status of 'Moderate'.
- River Churn – source to Perrots Brook: Ecological status of 'Moderate', chemical status of 'Fail', and overall status of 'Moderate'.

13.7.49 As outlined in paragraph 13.7.243, the WFD surface water body for Norman's Brook is inaccurate, and WFD surface water classifications do not extend to the tributaries of Horsbere Brook, Norman's Brook and the River Churn within the study area of the scheme.

Surface water quality

13.7.50 There are ten relevant EA Water Quality sampling points as shown on the EA's online Water Quality Archive[22]. A review of EA monitoring locations noted water quality sampling has been undertaken at various private and public wastewater treatment plants in the area. There are no routine river water quality sampling locations on the watercourses of interest.

13.7.51 Water quality at ten locations within Bushley Muzzard SSSI was monitored during four rounds between October and December 2018, following events of both low and high precipitation and a variation in flows (ES Appendix 13.11 Water Features Survey (Document Reference 6.4)).

13.7.52 Average pH readings of 8.06 were recorded across the monitoring period at all sites, with a range between 7.96pH and 8.25pH showing the watercourses to be slightly alkaline – consistent with the geological setting (ES Appendix 13.11 Water

Features Survey (Document Reference 6.4)). Following high levels of precipitation, pH was typically higher at the majority of locations.

13.7.53 Conductivity ranged between 660µS/cm and 740µS/cm, with higher results after prolonged periods of rainfall (ES Appendix 13.11 Water Features Survey (Document Reference 6.4)). All values were considered to be relatively high for freshwater watercourses, indicating a potential high dependency upon precipitation. Similarly, phosphates and nitrates recorded noticeably higher values following prolonged rainfall, with average results across all locations of approximately 8mg/l following prolonged rainfall and approximately 3mg/l following low or no rainfall.

13.7.54 Water quality monitoring undertaken to inform the baseline of the scheme has been undertaken at six locations across the study area which are shown on ES Figure 13.15 Water environment monitoring locations (Document Reference 6.3).

13.7.55 Over a range of flows, the pH was typically the lowest at SW3 located within the Frome catchment, within Bushley Muzzard SSSI. Lower pH values were also typical at SW5 and SW6 within the River Churn catchment. The average pH across all locations was 8.09pH, with maximum and minimum values of 8.53pH and 7.63pH, respectively, recorded across the monitoring period.

13.7.56 Conductivity values were generally the highest at SW3 and lowest at SW6. The average conductivity value recorded across all locations was 590.41 µS/cm, with maximum and minimum values of 909.32 µS/cm and 288.41 µS/cm, respectively, recorded across the monitoring period.

13.7.57 Turbidity values were typically low across all locations, particularly SW4, SW5 and SW6, consistent with the relatively low levels of disturbance within the catchments and watercourses. However, the highest value was recorded at SW5 (177.95NTU) on 16 December 2020. The highest turbidity values were consistently found at both SW1 and SW2, relative to other monitored locations. The average turbidity value recorded across all locations was 21.2NTU, with maximum and minimum values of 177.95NTU and 0.01NTU, respectively, recorded across the monitoring period.

13.7.58 Data of all parameters monitored is presented in ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4)

Surface water abstractions

13.7.59 Two surface water abstractions were identified during the water features survey. One abstraction is recorded near Primrose Vale Farm, to the north of Bentham, and another to the west of Whitcombe Reservoirs. These are shown on ES Figure 13.5 Hydrogeological study area and features (Document Reference 6.3). Neither is located within the study area for the scheme.

13.7.60 It is noted that there may be potential for further unlicensed abstractions from watercourses within the study area for the scheme. Should information on unlicensed supplies become available, individual risk assessments will be undertaken to assess potential impact and identify specific mitigation, where required.

13.7.61 Consultation has been undertaken to identify unlicensed abstractions as detailed in section 13.4 Assessment methodology.

Consented discharge to surface water

13.7.62 At the time of undertaking the assessment there have been seventeen consented discharges of treated sewage or unspecified combined sewage and trade effluent to surface waters within 1 kilometre of the scheme[23]. Of these, seven discharge licenses are still active and are located at Cotswold Hill Golf Club, The National Star Centre, Coberley Sewage Treatment Works, Cawley Manor Hotel, Green Dragon Inn and Greycote & Willow Farm. A summary of the consented discharges is presented in Table 13-6.

**Table 13-6 Consented surface water discharge licences within 1km of the scheme**

| Site Name | Site type | Receiving water | License status | Effluent description |
|---|---|---|---|---|
| Cotswold Hill Golf Club (1) | Business (recreation) | Tributary of River Churn | Active | Sewage discharges – final/treated effluent – not water company |
| Cotswold Hill Golf Club (2) | Business (recreation) | Tributary of River Churn | Active | Sewage discharges – final/treated effluent – not water company |
| Cotswold Hill Golf Club (3) | Business (recreation) | Tributary of River Churn | Revoked | Sewage discharges – final/treated effluent – not water company |
| The National Star Centre | Business | Ullenwood Stream (Tributary of River Churn) | Active | Sewage discharges – final/treated effluent – not water company |
| Nos 1 to 3 Moat Cottages (1) | Domestic property | Tributary of River Churn | Revoked | Sewage discharges – final/treated effluent – not water company |
| Nos 1 to 3 Moat Cottages (2) | Domestic property | Tributary of River Churn | Revoked | Sewage discharges – final/treated effluent – not water company |
| Coberley (1) | Business | Ullenwood Stream (Tributary of River Churn) | Revoked | Sewage discharges – sewer storm overflow – water company |
| Coberley (2) | Business | Ullenwood Stream (Tributary of River Churn) | Revoked | Sewage discharges – sewer storm overflow – water company |
| Ullenwood Manor | Dentist/ hospital/ nursing home (medical)/ human health | Ullenwood Stream (Tributary of River Churn) | Revoked | Sewage discharges – final/treated effluent – not water company |
| Coberley Sewage Treatment Works (1) | Wastewater treatment works (water company) | Ullenwood Stream (Tributary of River Churn) | Revoked | Sewage discharges – final/treated effluent – water company |
| Coberley Sewage Treatment Works (2) | Wastewater treatment works (water company) | Ullenwood Stream (Tributary of River Churn) | Revoked | Sewage discharges – final/treated effluent – water company |
| Coberley Sewage Treatment Works (3) | Wastewater treatment works (water company) | Ullenwood Stream (Tributary of River Churn) | Active | Sewage discharges – final/treated effluent – water company |
| Cawley Manor | Business | River Churn | Revoked | Sewage discharges – final/treated effluent – not water company |

| Site Name | Site type | Receiving water | License status | Effluent description |
|---|---|---|---|---|
| Cawley Manor Hotel | Business | River Churn | Active | Sewage & trade combined – unspecified |
| Green Dragon Inn (1) | Business | River Churn | Revoked | Sewage discharges – final/treated effluent – not water company |
| Green Dragon Inn (2) | Business | River Churn | Active | Sewage discharges – final/treated effluent – not water company |
| Greycote & Willow Farm | Domestic property (single) (including farmhouse) | Tributary of Horsbere Brook | Active | Sewage discharges – final/treated effluent – not water company |

**Flood risk**

Fluvial flood risk

13.7.63 The scheme alignment is located entirely in Flood Zone 1[24], which is defined as having a risk of flooding from fluvial and tidal sources of less than 1 in 1,000 (0.1%) in any year, and as a result is defined as being at 'low' risk.

13.7.64 The scheme is located within 1 kilometre of Flood Zones 2 and 3 for the River Frome and Horsbere Brook at the eastern and western extents of the scheme respectively[25].

13.7.65 Existing flood risk from EA mapping is shown on ES Figure 13.2 Existing flood risk (Document Reference 6.3) and baseline flooding of the tributary of Norman's Brook is shown on ES Figure 13.21 Crickley Hill Surface Water Flooding – Baseline (Document Reference 6.3). Fluvial flood risk related to the tributary of Norman's brook is further detailed in ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4).

Pluvial flooding

13.7.66 Sections of the scheme alignment are indicated on the EA mapping to be at risk of pluvial flooding (from surface water sources). The mapping does not distinguish between areas at risk of flooding purely from surface water runoff (specifically during heavy rainfall events) and areas at risk from small watercourses that are too small to be included on fluvial flood risk mapping.

13.7.67 At the Birdlip junction, the scheme crosses an area of 'high' surface water flood risk[26] that appears to coincide with the head of a dry valley and may be associated with an ephemeral watercourse or springs within the dry valley. An area of 'low' surface water flood risk is recorded to the north-east of the scheme at the A436 and Ullenwood Manor Road crossroads and is associated with a tributary of the River Churn. An area of 'low' to 'medium' surface water flood risk is identified to the north of the scheme area near Crickley Hill Country Park access road. Areas of 'low' to 'high' surface water flood risk coincide with the tributary of Norman's Brook flowing down Crickley Hill, to the south of the existing road. The level of surface water flood risk increases to 'high' risk towards Crickley Hill Farm.

Groundwater flooding

13.7.68 The BGS Groundwater Susceptibility dataset[27] indicates there is the potential for groundwater flooding to occur to the west of Crickley Hill and at Nettleton Bottom, in the River Frome headwater valley. Along Crickley Hill and up to the Severn/Thames catchment divide, and in the southern extent of study area, there is a limited potential for groundwater flooding to occur. Existing groundwater flooding susceptibility is shown on ES Figure 13.7 Groundwater flooding susceptibility (Document Reference 6.3).

### Hydrogeology

Overview

13.7.69 The hydrogeology of the Cotswolds is influenced by the complex relationship between aquifers, aquitards, periglacial geomorphology and surface water – groundwater interactions. An idealised model of the regional hydrogeological processes is presented in Plate 13-1. In the study area, mass movement deposits cover the Lias Group and the Fuller's Earth Formation is laterally continuous.

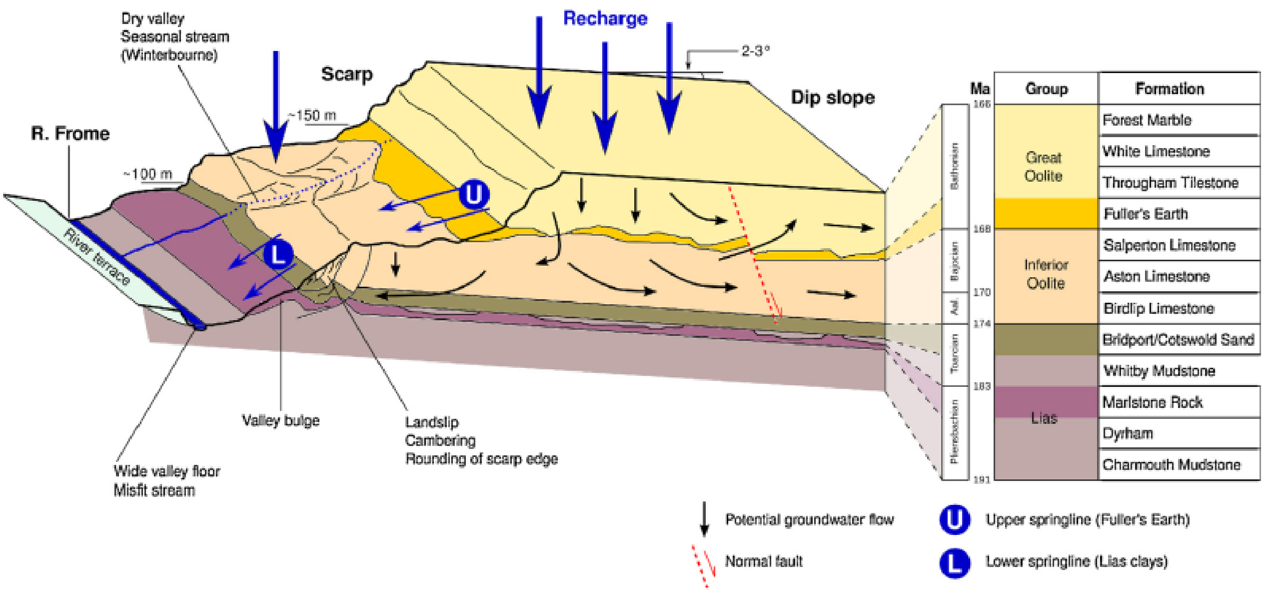


**Plate 13-1 Conceptual hydrogeological model of the mid Cotswolds[28]**

13.7.70 Full details of geological conditions are presented in ES Chapter 9 Geology and soils (Document Reference 6.2). Hydrogeological interactions are detailed in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4) and summarised below. A summary of the aquifers in the study area is presented in Table 13-7.

Superficial deposits

13.7.71 The extent of mapped superficial deposits is limited within the study area, as shown on ES Figure 9.3 Geological map (Document Reference 6.3) of ES Chapter 9 Geology and soils (Document Reference 6.2). Cheltenham Sand and Gravel superficial deposits are present at the western end of the scheme, while alluvium, comprising clay, silt sand and gravel, is mapped on the northern side of Bushley Muzzard SSSI. Both superficial deposits are designated by the EA as Secondary A aquifers indicating they are "permeable layers capable of supporting water supplies at a local rather than a strategic scale, and in some cases forming an important source of base flow to rivers".

13.7.72 Mass movement deposits are mapped across the Cotswold escarpment and head deposits are located within the Churn Valley (near Shab Hill Farm) and the Frome Valley (near Stockwell-Nettleton Bottom). These deposits typically comprise an assortment of the underlying parent geology within a matrix of largely cohesive material. The ground investigation indicates these deposits are clay dominated with sand and gravel lenses, which are locally recharged and often associated with springs and seepages. The mass movement and head deposits are not EA designated aquifers, however groundwater within these deposits supports many of the groundwater-surface water interaction features on the Cotswold escarpment and valleys in the region.

13.7.73 Groundwater flow through the superficial deposit aquifer is dominated by intergranular flow where the permeability will support it. Coarse grained lenses within the clay dominated deposits are likely to facilitate local zones of groundwater flow and may create zones of perched groundwater. These more permeable zones are anticipated to promote the emergence of some groundwater springs within the Crickley Hill area.

13.7.74 The superficial deposits are unconfined however within the clay dominated material there may be some local confinement of water bearing, coarse grained lenses. Where this confinement occurs, locally elevated porewater pressures may be present within the mass movement deposits. Groundwater levels are likely to be relatively variable and shallow within the superficial deposit aquifer.

Great Oolite Group

13.7.75 Jurassic-aged bedrock formations comprising Great Oolite Group, the Inferior Oolite Group and the Lias Group underlie the study area. Further details on underlying geology are described in ES Chapter 9 Geology and soils (Document Reference 6.2) and shown on ES Figure 9.3 Published geology (Document Reference 6.3).

13.7.76 Limestones within the Great Oolite Group are considered the main water bearing formations that allow for groundwater movement in this geological group. In the scheme area, the Great Oolite limestones are unconfined and groundwater perches above the basal Fuller's Earth Formation. This perched groundwater promotes the development of groundwater springs along the boundary of the limestones over mudstone.

13.7.77 Due to the low primary matrix permeability of limestone, groundwater flow is mainly via secondary fracture flow and can locally be via tertiary karst flow (voids and conduit). Karst features can increase aquifer transmissivity and decrease aquifer storage. Evidence from the ground investigation, including downhole geophysics and geological logging, indicates there are metre scale voids in the Great Oolite Group limestone between the Shab Hill and the Shab Hill Barn faults. To the south of the Shab Hill Barn Fault, where the limestone of the Great Group is thin (up to 4m thick), there is little potential for voids within the limestone.

13.7.78 Where the Great Oolite limestone formations transition to the Fuller's Earth Formation, limestones are likely to be interbedded by mudstones with the frequency and thickness of mudstone beds increasing with depth. As a result, the effective horizontal hydraulic conductivity of the transition zone is dominated by limestone beds. The vertical conductivity of the transition zone is anticipated to be limited by the hydraulic conductivity of the mudstone.

13.7.79 Limestones within the transition zone are anticipated to be recharged via leakage through the overlying interbedded mudstone where fractured. Limestone beds are near surface and will be directly recharged rainfall.

13.7.80 The Fuller's Earth Formation is a grey mudstone with limestone beds, which is the basal formation of the Great Oolite Group. In the study area the Fuller's Earth Formation aquitard is laterally continuous below the Great Oolite Group limestones and above the Inferior Oolite Group. South of Stockwell fault, the Fuller's Earth Formation is at ground surface.

13.7.81 The Great Oolite Group (excluding the Fuller's Earth Formation) is classified as a Principal aquifer, described as "layers of rock or drift deposits that have high intergranular and/or fracture permeability – meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale." The Fuller's Earth Formation is classified by the EA as an Unproductive Aquifer associated with "low permeability [and] negligible significance for water supply or river base flow". Aquifer designations are shown on ES Figure 13.6 Aquifer designations (Document Reference 6.3).

Inferior Oolite Group

13.7.82 The Inferior Oolite limestone aquifer forms the crest of the Cotswold escarpment and extends south-east from the escarpment (shown on ES Figure 9.3 Geological map (Document Reference 6.3)). The aquifer is largely unconfined, however in the southern portion of the scheme it is partially confined by the Fuller's Earth Formation mudstone aquitard.

13.7.83 Evidence from the ground investigation, including downhole geophysics and geological logging, suggests abundant to frequent voids within the Birdlip Limestone Formation. Logged voids ranged from 10mm to 140mm, varying in shape from rounded to irregular and predominantly iron stained with occasional sandy clay infill. Geophysical evidence suggests that voids up to 1m in length are present. Voids were logged at varying depths through the Birdlip Limestone Formation and were logged towards the base of the across the entire scheme.

13.7.84 It is possible that some of the fissures and gulls along the escarpment are groundwater flow paths that may feed groundwater springs at the Inferior Oolite limestone and Lias Group boundary or groundwater springs emerging from the mass movement deposits.

13.7.85 The Inferior Oolite Group is classified by the EA as a Principal aquifer. Aquifer designations are shown on ES Figure 13.6 Aquifer designations (Document Reference 6.3).

Lias Group

13.7.86 The Whitby Mudstone Formation, Dyrham Formation and Charmouth Mudstone Formation are the thicker formations within the Lias Group and are the prime influence for the group's hydraulic properties. Largely comprising mudstone and silty mudstone, the formations have relatively low permeabilities and function as aquitards.

13.7.87 The Bridport Sand and Marlstone Rock formations are relatively thin geological units that influence more localised groundwater processes.

13.7.88 The Bridport Sand Formation generally includes mudstone and siltstone units which perch groundwater in the overlying limestone of the Inferior Oolite Group. Groundwater flow through the Bridport Sand Formation is likely to be dominated by secondary fracture permeability but locally there can be a component of flow through the rock matrix.

13.7.89 The Marlstone Rock Formation can be greatly affected by cambering. The cambering processes would be more pronounced closer to the edge of the escarpment. Higher hydraulic conductivity within the Marlstone Rock Formation, relative to the overlying Whitby Mudstone Formation, may promote leakage from the mudstones and locally form a spring-line at the base of the Marlstone Rock Formation.

13.7.90 In the study area, BGS present the stratigraphy encompassing the upper parts of the Lias Group and the lower parts of the Inferior Oolite Formation as the 'Lias Group and Inferior Oolite (undifferentiated)'. Owing to this stratigraphy being combined, the Lias Group and Inferior Oolite (undifferentiated) is designated by the EA as a Principal aquifer. Based on descriptions of the Lias Group, the Bridport Sand Formation is considered a Secondary A aquifer. However, the site-specific information in this report is based upon site investigation data from the scheme, thereby this provides a higher resolution to the EA mapping in the DCO Boundary. As such the properties of the aquifers in this area are based on site-specific information.

13.7.91 In the study area the Charmouth Mudstone Formation is classified by the EA as a Secondary Undifferentiated aquifer, described as "both minor and non-aquifer in different locations due to the variable characteristics of the rock types".

Structural geology

13.7.92 Structurally the bedrock groups dip between 2º and 5º towards the east and south-east and are intersected by inferred faults in the region. It is considered that faulting throughout the region is providing flow paths for groundwater, particularly between the Great Oolite Group and Inferior Oolite Group. The location of the faults has been reviewed and based on evidence gathered through geomorphological, ground investigation and surface geophysics information revised fault locations have been identified and adopted for the ES. The details are presented in ES Appendix 9.2 Preliminary ground investigation report (Document Reference 6.4). The location of the faults is shown on ES Figure 9.3 Geological map (Document Reference 6.3).

13.7.93 Gulls and karst features mostly occur at the Cotswold escarpment edge. Further away from the Cotswold escarpment the only karst features recorded include the dry valley at Shab Hill and voids within the Inferior Oolite Group. Self & Boycott (2004) identified in the Stroud area that the tributaries of the River Frome have incised deeply through the Fuller's Earth Formation and into the Great Oolite Limestones, but no gull caves are known[29]. Similar conditions were found in the Great Oolite Group at the southern end of the scheme.

Hydrogeological conceptual model

13.7.94 Local hydrogeological conditions along the scheme are shown on a series of conceptual models (refer to ES Figure 13.10 Groundwater conceptual model (Document Reference 6.3) and ES Figure 13.17 Groundwater conceptual model locations (Document Reference 6.3)) and detailed descriptions are presented in

ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4). A summary of the aquifers in the study area is presented in Table 13-7.

## Table 13-7 Summary of hydrogeological units

| Age | Group | Formation | EA designation | Description | Thickness | Hydrogeological properties |
|---|---|---|---|---|---|---|
| Quaternary | - | Cheltenham Sand and Gravel | Secondary A aquifer | Fine to medium grained sand, seams of limestone gravel | 0m to 2m | • Groundwater flow through relatively high permeability, intergranular matrix.<br>• Directly recharged. |
| | | Superficial deposits (alluvium, mass movement deposits and head deposits) | Alluvium – Secondary A aquifer<br>Mass movement and head deposits – no aquifer designation | Largely cohesive material with non-cohesive lenses | 0m to 23m | • Variable hydraulic conductivity. Groundwater flow through intergranular matrix.<br>• Directly recharged.<br>• Seasonal groundwater levels.<br>• Localised springs were more permeable zones are present such as sand and gravel lenses or toppled limestone blocks.<br>• Springs may be tufa forming if the permeable zones occur in limestone dominant material. |
| Middle Jurassic | Great Oolite Group<br><br>(168 – 165Ma) | White Limestone Formation | Principal aquifer | Limestone aquifer with clay beds | 10m to 20m | • Highly fractured. Potential for metre scale voids between Shab Hill Barn fault and Shab Hill fault.<br>• Iron staining and calcite precipitate on fractures.<br>• Deep unsaturated zone.<br>• Seasonal groundwater levels where aquifer is largely dry during summer months. |
| | | Hampen Formation | | Sandy and ooidal limestone aquifer with clay and marl beds | | |
| | | Througham Formation | | Interbedded calcareous sandstone, variably oolitic limestone and calcareous mudstone and siltstone | 0m to 10m | • Large anisotropy in hydraulic conductivity.<br>• Seasonal groundwater levels. |
| | | Fuller's Earth Formation | Unproductive aquifer | Mudstone aquitard with limestone beds | 0m to 15m | • Sub-horizontal fracturing.<br>• Relatively low permeability.<br>• Forms a spring line with overlying Great Oolite limestones. |

| Age | Group | Formation | EA designation | Description | Thickness | Hydrogeological properties |
|---|---|---|---|---|---|---|
| | Inferior Oolite Group (175 – 168Ma) | Salperton Limestone | Principal aquifer | Shelly, ooidal limestone aquifer | 0m to 40m | • Fractured with cambering, gull and enhanced dissolution features.<br>• Frequent, iron stained voids towards base of aquifer.<br>• Deep unsaturated zone.<br>• Seasonal groundwater levels, where aquifer is largely dry during summer.<br>• Directly recharged where at ground surface.<br>• Possible indirect recharge by leakage from overlying head deposits and Great Oolite Group.<br>• Springs occur in the Inferior Oolite Group associated with the Shab Hill barn fault. |
| | | Aston Limestone | | Shelly, sandy limestone aquifer | | |
| | | Birdlip Limestone | | Ooidal, sometimes sandy limestone aquifer with sandy clay layers | | |
| Lower Jurassic | Lias Group (200 – 175Ma) | Bridport Sand Formation | Principal aquifer (see paragraph 13.4) | Sandy mudstone and fine-grained sandstone – minor aquifer | 0m to 10m | • Discontinuous presence within the study area.<br>• Hydraulic connection with base of Inferior Oolite.<br>• Fracture dominated flow.<br>• Seasonal groundwater table.<br>• Indirectly recharged. |
| | | Whitby Mudstone Formation (WMF) | | Mudstone aquitard with limestone beds at base | 12m to 98m[30] | • Relatively low permeability.<br>• Potential to form a spring line with overlying Inferior Oolite Group and Bridport Sand.<br>• Fissured clays in weathered zone. |
| | | Marlstone Rock Formation (within the WMF) | | Ferruginous, ooidal limestone and sandstone – minor aquifer | 0m to 5m[31] | • Fracture dominated flow.<br>• Recharged via leakage from overlying formations. |
| | | Dyrham Formation | | Silty mudstone and siltstone aquitard | 15m to 54m[32] | • Relatively impermeable. |
| | | Charmouth Mudstone Formation | Secondary Aquifer (Undifferentiated) | Mudstone aquitard with thin beds and nodules of limestone | 120m to 284m[33] | • Relatively impermeable.<br>• Localised zones of iron staining on fractures. |

Catchment Abstraction Management Strategy (CAMS)

13.7.95 The scheme is located within three CAMS areas as designated by the EA. These are listed below and presented in Figure 13.8 Catchment Abstraction Management Strategy (Document Reference 6.3):

- The Severn Corridor – up to approximately Ch. 2+100, west of the groundwater divide.
- The Cotswolds – between approximately Ch. 2+100 and Ch. 3+800, east of the groundwater divide.
- The Severn Vale – from approximately Ch. 3+800, west of the groundwater divide.

13.7.96 The availability of water for abstraction within the catchments is presented in Table 13-8.

**Table 13-8 CAMS water resource availability summary**

| Flow type | Severn corridor | Cotswolds | Severn Vale |
|---|---|---|---|
| $Q_{95}$ (lowest) | Limited water available | Water not available | Limited water available |
| $Q_{70}$ | Water available | Water not available | Limited water available |
| $Q_{50}$ | Water available | Water not available | Limited water available |
| $Q_{30}$ (highest) | Water available | Restricted water available | Limited water available |

Groundwater WFD catchments

13.7.97 The scheme is located over two river basin districts: the Severn to the west and the Thames to the east. The topographical catchment boundary along the Upper Cotswolds Plateau generally correlates to the groundwater divide between the Severn and Thames catchments[34]. These river basin districts are divided into three WFD groundwater bodies, where two are within the Severn Vale catchment and one is within the Thames catchment[35]. A summary of the WFD groundwater bodies is presented in Table 13-9 and the extent of the groundwater WFD catchments is shown on ES Figure 13.4 WFD Groundwater bodies (Document Reference 6.3).

13.7.98 The superficial deposit aquifers are not specifically designated as WFD groundwater bodies. However, it is anticipated they are hydraulically connected to the relevant underlying designated WFD groundwater bodies presented in Table 13-9.

13.7.99 The Severn Vale catchment is divided into the Severn Vale – Jurassic Limestone Cotswold Edge South (ID GB40901G305700) and the Severn Vale – Secondary Combined (ID GB40902G204900) groundwater bodies. These groundwater bodies locally drain towards the west into the River Frome, Norman's Brook and their tributaries.

13.7.100 The Severn Vale – Jurassic Limestone Cotswold Edge South groundwater body generally correlates to areas of the Great Oolite Group, Inferior Oolite Group and Upper Lias Group, west of the groundwater divide.

13.7.101 The Severn Vale – Secondary Combined groundwater body includes areas underlain by the Charmouth Mudstone Formation at the base of the Lias Group at the western end of the scheme.

13.7.102 The Thames catchment in the study area comprises solely of the Burford Jurassic WFD groundwater body (ID GB40601G600400). The Burford Jurassic groundwater body generally correlates to the Great Oolite Group and the Inferior Oolite Group limestones that drain towards the south-east where the Inferior Oolite is confined by the Fuller's Earth Formation. The aquifers locally feed into the River Churn and its tributaries in the south-east.

13.7.103 The overall 2019 status of both the Jurassic Limestone Cotswolds Edge South and Secondary Combined groundwater bodies is 'Good', however the Burford Jurassic is 'Poor'.

**Table 13-9 Summary of WFD groundwater bodies**

| Groundwater body name | Burford Jurassic | Severn Vale – Jurassic Limestone Cotswolds Edge South | Severn Vale – Secondary Combined |
|---|---|---|---|
| Groundwater body ID | GB40601G600400 | GB40901G305700 | GB40902G204900 |
| Operational catchment | Burford Jurassic | Severn Vale – Jurassic Limestone Cotswolds Edge South | Severn Vale – Secondary Combined |
| Management catchment | Thames GW | Severn England GW | Severn England GW |
| River basin district | Thames | Severn | Severn |
| Current overall status | Poor (2019) | Good (2019) | Good (2019) |
| Current quantitative status | Good (2019) | Good (2019) | Good (2019) |
| Current chemical status | Poor (2019) – poor nutrient management (diffuse sources) and private sewage treatments (point sources) | Good (2019) | Good (2019) |
| Quantitative objective | Good by 2015 | Good by 2015 | Good by 2015 |
| Chemical objective | Good by 2027 | Good by 2015 | Good by 2015 |
| Protected area | Drinking water protected area and nitrates directive. | Drinking water protected area and nitrates directive. | Drinking water protected area and nitrates directive. |

13.7.104 The scheme alignment is underlain by Principal aquifers with a current WFD status of 'Good' and 'Poor' and a Secondary Undifferentiated aquifer with a status of 'Good', shown in Table 13-9. The majority of the extent of the scheme alignment is not located within a SPZ, however east of Stockwell the scheme runs adjacent to an SPZ3 for the Baunton abstraction. A summary of the geological aquifers and how they align with the WFD groundwater bodies is presented in Table 13-10.

### Table 13-10 Underlying aquifer characteristics

| Name | WFD groundwater body | Key characteristics |
|---|---|---|
| Superficial deposits – Secondary A aquifer | Not assessed as a WFD groundwater body by the EA | Aquifer may be a source of baseflow to tributaries feeding into tributaries of the River Frome or the Bushley Muzzard SSSI. |
| Lias Group – Secondary Undifferentiated aquifer | Severn Vale – Secondary Combined | Springs issuing from the contact of the Lias Group and Inferior Oolite supply the River Frome. |
| Inferior Oolite – Principal aquifer | Severn Vale – Jurassic Limestone Cotswolds Edge South | Aquifer supports the Crickley Hill and Barrow Wake SSSI, springs, river headwaters including Norman's Brook, public water supply and private water abstractions. |
| Great Oolite – Principal aquifer | Burford Jurassic | Aquifer providing private water supply and local public water supply where the study area is within the SPZ3. Supports Bushley Muzzard SSSI, springs and headwaters of rivers, including the River Churn, within the catchment. |

<u>Hydraulic conductivity</u>

13.7.105 Aquifer testing was conducted during the Phase 1 and Phase 2A ground investigations to estimate the hydraulic conductivity the following bedrock formations: Fuller's Earth Formation (Great Oolite Group), Birdlip Limestone Formation (Inferior Oolite Group), Inferior Oolite Group and Bridport Sand Formation (Lias Group). A combination of constant head and variable head tests were used depending upon saturated aquifer thickness. A summary of the testing results is presented in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4) and test reports are included in ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4).

<u>Groundwater levels</u>

13.7.106 A groundwater monitoring network has been progressively installed across the scheme as part of the wider ground investigation programme with locations shown on ES Figure 13.9 Groundwater monitoring locations (Document Reference 6.3). They are distributed along the scheme alignment with some locations further away from the scheme to inform the regional understanding of the aquifers, landslip hazard risk in Crickley Hill and potential impacts to environmentally sensitive sites like the Bushley Muzzard SSSI. The following aquifer units have been monitored:

- Mass movement deposits of Crickley Hill – 16No installations
- Great Oolite Group limestones – 7No installations
- Fuller's Earth Formation – 3No installations
- Inferior Oolite Group – 23No installations
- Bridport Sand Formation – 2No installations
- Lias Group undifferentiated mudstones – 8No installations

13.7.107 The review of groundwater level monitoring was undertaken for the individual aquifer units with consideration of the geographical extent of the scheme and its elements. This is presented in detail in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4) and summarised in Table 13-11. Refer to the following figures for a graphical presentation of groundwater level monitoring (all Document Reference 6.3):

- ES Figure 13.11 Groundwater contours – Inferior Oolite Group, seasonal minimum levels.
- ES Figure 13.12 Groundwater contours – Inferior Oolite Group, seasonal maximum levels.
- ES Figure 13.13 Groundwater contours – Great Oolite Group, minimum levels.
- ES Figure 13.14 Groundwater contours – Great Oolite Group, maximum levels.

13.7.108 Details of the response zones are summarised in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4) with exploratory hole logs and groundwater level monitoring records shown in ES Appendix 9.3 Ground investigation factual report (Document Reference 6.4).

### Table 13-11 Scheme elements and anticipated groundwater levels

| Scheme elements | Chainage (m) | Maximum change in formation level | Approximate groundwater levels | Approximate maximum groundwater levels | Observed ranges in groundwater level |
|---|---|---|---|---|---|
| Crickley Hill approach | 0+000 to 0+500 | 0.5m | No monitoring data available – within an area of potential groundwater flooding | | |
| Earth bunding and widening of A417 up Crickley Hill, diversion of the tributary of Norman's Brook<br>Stabilisation of landslide deposits at Crickley Hill | 0+500 to 1+700 | 10.8m (Mass movement deposits) | Typically, between 2m and 3.3m below ground level, with some groundwater levels up to 11m below ground level | Ground surface, due to prevalence of springs | Seasonal variations between 0.6m and 4.0m and responsive to rainfall inputs |
| Air Balloon cutting | 1+700 to 3+000 | -14.9m (Inferior Oolite Group) (Ch. 1+700 – 1+800 at lowest elevation at 208.6 to 216.5mOD) | Deep unsaturated zone to 210mAOD | 212.3mAOD | Seasonal groundwater levels (up to 4.2m), largely dry over summer months. |
| Shab Hill junction | 3+000 to 3+500 | -1.3m (Ch. 3+000 – 3+100, with lowest | 269mAOD at western side of junction and 215.9mAOD in | Up to 269.4mAOD in | To be confirmed within the Great Oolite limestones. |

| Scheme elements | Chainage (m) | Maximum change in formation level | Approximate groundwater levels | Approximate maximum groundwater levels | Observed ranges in groundwater level |
|---|---|---|---|---|---|
| | | elevation at 270mOD)) 20.1m (both Great Oolite Group) | dry valley, within Great Oolite limestone | Great Oolite limestone. | |
| | | Not impacted (Inferior Oolite Group) | 200mAOD within underlying Inferior Oolite limestone. | 222mAOD within underlying Inferior Oolite limestone. | 4.2m variation recorded in Inferior Oolite limestone thus far. |
| Cuttings south of Shab Hill | 3+500 to 5+700 | -8.2m with lowest elevation at 267mOD) (Great Oolite Group) | From CH3+600 to CH5+000, decreasing from 279.5mAOD to 267.3mAOD in Great Oolite limestone. | From CH3+600 to CH4+500, decreasing from 284.5mAOD to 273.1mAOD in Great Oolite limestone | Seasonal groundwater levels, responsive to rainfall, with 2.6 to 7.4m variation. |
| | | Not impacted (Inferior Oolite Group) | 200mAOD in underlying Inferior Oolite limestone, with deep unsaturated zone. | 207.7mAOD in underlying Inferior Oolite limestone. | Seasonal groundwater levels (up to 2.8m), largely dry during summer months in underlying Inferior Oolite limestone. |

Note: In the '*Maximum change in formation level*' column, negative numbers indicate a cutting and positive numbers indicate fill relative to existing ground level

<u>Springs</u>

13.7.109 Groundwater springs are ubiquitous within the Cotswolds escarpment region (ES Figure 13.5 Hydrogeological study area and features (Document Reference 6.3) and ES Appendix 13.4 Water quality assessment and ES Appendix 13.11 Water Features Survey (both Document Reference 6.4)). Springs in the study area feed headwaters of Norman's Brook, an unnamed tributary of the River Frome and unnamed tributaries of the River Churn, as detailed in Table 13-13. Most springs in the study area are associated with the superficial deposits but there are also several limestone springs. Springs recorded in the study area are presented on ES Figure 13.9 Groundwater monitoring locations (Document Reference 6.3).

13.7.110 Many of the springs (both superficial and limestone) are seasonal features that dry out in response to lower groundwater levels within the respective source aquifer. The limestone springs are often linked to major fissures or gulls and generally respond to storm events.

13.7.111 Mapped limestone springs in the region correlate to bedrock formations and boundaries or structural features including:

- The Great Oolite limestones and the Fuller's Earth Formation.
- The Inferior Oolite Group (in spatially limited connection with Bridport Sand. Formation) and Lias Group mudstone.

- Shab Hill Barn fault.
- Cally Hill fault.

13.7.112 Springs also emerge from the mass movement deposits along the Cotswold Escarpment where preferential flow paths have developed through more permeable zones of the mixed material.

Superficial carbonate deposits

13.7.113 Superficial carbonate precipitates are terrestrial deposits[36] which form a variety of environments and are commonly found in areas with limestone bedrock. Common names for terrestrial carbonate deposits, 'tufa' and 'travertine', are often used interchangeably within karst literature. The naming convention adopted by Ford and Williams (2007) has been applied to this assessment where tufa refers to grainy deposits accreting to algal filaments, plant stem and roots at springs, along banks of watercourses, lake edges, etc.[37]

13.7.114 Carbonate deposits typically form due to the precipitation of calcium carbonate, when carbon dioxide degasses from supersaturated carbonate waters:

$$\boldsymbol{Ca^{2+} + 2HCO^{3-} \Leftrightarrow CaCO_3 + CO_2 + H_2}$$

13.7.115 Potential tufa formations were identified along the tributary of Norman's Brook during the water features survey (ES Appendix 13.11 Water Features Survey (Document Reference 6.4)) and through biodiversity tufa springs surveys (ES Appendix 8.25 Tufa-forming springs: selection of potential compensation sites (Document Reference 6.4)). The biodiversity tufa springs surveys have also identified tufa formations in the valley of the head of the Frome including the area of Bushley Muzzard SSSI. The locations are shown on ES Figure 13.5 Hydrogeological study areas and features (Document Reference 6.3).

13.7.116 Based on the geological setting close to the tributary of Norman's Brook, it is anticipated that the tufa formations are depositing from groundwater emerging from superficial deposits that includes some limestone parent material. The high permeability lenses of the superficial deposits allow significant surface area contact with groundwater, which can become hard relatively quickly

13.7.117 The habitat value of the carbonate deposits is discussed in ES Chapter 8 Biodiversity (Document Reference 6.2). The geological value of tufa deposits is discussed in ES Chapter 9 Geology and soils (Document Reference 6.2).

Dry valleys

13.7.118 Dry valleys in limestone terrains are glaciofluvial karst features. Such valleys originally formed by periglacial streams that incised into the limestone bedrock, often creating steep sided gorges and ravines. Subsequently, the streams drained elsewhere, often being lost to ground as losing streams[38]. Dry valleys are relic topographical features, but seasonal streams may flow episodically[39,40]. The dry valleys identified within the study area are shown on ES Figure 13.5 Hydrogeological study areas and features (Document Reference 6.3).

Groundwater abstractions

13.7.119 The majority of the study area is not located within a designated groundwater SPZ. However, the SPZ for the Baunton public water supply abstraction (approximately 7.5 miles (12 kilometres) south-east of the scheme) extends into the study area within the Thames groundwater catchment, as shown on ES Figure 13.5 Hydrogeological study areas and features (Document Reference 6.3). The Baunton abstraction SPZ3 intersects part of the scheme where the works in these areas are primarily within the Great Oolite aquifer. The southern end of the scheme is approximately 1.7 miles (2.8 kilometres) from SPZ2 and 2.1 miles (3.4 kilometres) from SPZ1 in the south-east.

13.7.120 The Baunton public water supply is abstracting water from the Inferior Oolite Group aquifer. The Fuller's Earth Formation hydraulically separates the design elements in the Great Oolite Group from the underlying Inferior Oolite Group.

13.7.121 There are no further recorded licensed abstractions that are known of within the study area.

13.7.122 The water features survey (see ES Appendix 13.11 Water Features Survey (Document Reference 6.4)) identified 16 potentially unlicensed abstractions, boreholes and wells within the study area. The locations are shown on ES Figure 13.5 Hydrogeological study areas and features (Document Reference 6.3). Many of these features were either not in use or details of their usage and groundwater source were not obtainable. Borehole dimensions are currently only available for two locations. Should the assessments indicate an impact on these locations, these will be revisited at detailed design to obtain further details.

13.7.123 Two unlicensed abstractions identified during the water features survey are used for drinking water supply. The first unlicensed abstraction is a piped spring shared between a private dwelling and Crickley Hill Tractors (both at Grove Farm), which is likely to be sourced from the Inferior Oolite Group. The second unlicensed abstraction is a spring at Bushley Muzzard SSSI to supply Watercombe Farm, which is likely to be sourced from the Great Oolite Group.

13.7.124 It is noted that there may be potential for further unlicensed abstractions within the study area.

13.7.125 Consultation has been undertaken to identify unlicensed abstractions as detailed in section 13.4 Assessment methodology.

Consented discharge to groundwater

13.7.126 There are nine consented discharges of treated sewage or unspecified combined sewage and trade effluent to land and underground strata recorded within 1 kilometre of the scheme[41]. Of these, three discharge licenses are still active and are located at Air Balloon public house, Crickley Hill and the Birdlip wastewater treatment works approximately 1 kilometre west of the scheme. A summary of the consented discharges is presented in Table 13-12. The locations are shown on ES Figure 13.5 Hydrogeological study areas and features (Document Reference 6.3).

### Table 13-12 Consented groundwater discharge licences within 1km of the scheme

| Site Name | Site type | Receiving water | License status | Effluent description |
|---|---|---|---|---|
| Air Balloon public house | Food and beverage services | To ground | Revoked | Sewage discharges – final/treated effluent – not water company |
| Air Balloon public house | Wastewater treatment works (not water company) | Underground strata (soakaway) | Active | Sewage and trade combined – unspecified |
| Air Balloon public house | Food and beverage services | Underground strata | Revoked | Sewage and trade combined – unspecified |
| Air Balloon public house | Wastewater treatment works (not water company) | Underground strata (soakaway) | Revoked | Sewage and trade combined – unspecified |
| Birdlip wastewater treatment works | Wastewater/sewage treatment works (water company) | Groundwater into infiltration system | Active | Sewage discharges – final/treated effluent – water company |
| Crickley cottages | Domestic property (single) (including farmhouse) | Underground strata | Active | Sewage discharges – final/treated effluent – not water company |
| Hardings barn | Domestic property (single) (including farmhouse) | Inferior oolite | Revoked | Sewage discharges – final/treated effluent – not water company |
| Hardings barn | Domestic property (single) | Inferior oolite | Revoked | Sewage discharges – final/treated effluent – not water company |
| Ullenwood manor | Dentist/hospital/nursing home (medical)/human health | Land | Revoked | Sewage discharges – final/treated effluent – not water company |

<u>Rainfall and recharge</u>

13.7.127 Rainfall data for the Ebsworth monitoring station approximately 3.4 miles (5.4 kilometres) south-west of the scheme has been obtained and is presented in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4). The mean annual rainfall in the area over the past 12 years is 868mm. Seasonal trends in rainfall were observed, where the average monthly rainfall between October to January varies between 87mm and 109mm. Between February and August the average monthly rainfall is lower and between 44mm and 81mm.

13.7.128 Over the groundwater monitoring period from February 2018 to May 2019, the monthly rainfall was below average, indicating a 'drying period' where available recharge was likely lower than average. From June 2019 to October 2020, higher than average monthly rainfall was recorded so the available recharge was likely to be higher than average. As a result, peak groundwater levels recorded over the winter period in late 2019 and early 2020, are likely to be higher than average.

13.7.129 Direct recharge of the Great Oolite Group aquifer primarily occurs within the Thames catchment and the Inferior Oolite Group aquifer is across the Severn and Thames catchments. Rainfall and potential evapotranspiration vary over the catchment area with rainfall being higher in the west and also increasing with topography[42] – both correlating to the location of the scheme in the catchment.

13.7.130 The mean annual recharge is 370mm per annum[43]. However, the amount of recharge is expected to vary as Morgan-Jones and Eggboro (1981) noted in the hydraulic years of 1975 and 1976 where recharge was 100mm and 630mm respectively.

13.7.131 The superficial deposit aquifers are recharged by a variety of mechanisms including rainfall infiltration, runoff from low permeability mudstones and groundwater draining from limestone aquifers higher in the landscape. It is possible that limestone inclusions within mudstone formations and the Marlstone Rock Formation could also be locally, hydraulically linked to the superficial deposit aquifer. In the Churn and Frome valleys, the superficial deposits may be leaking into the underlying Inferior Oolite limestones.

13.7.132 The Great Oolite limestone is recharged directly by rainfall. The underlying Fuller's Earth Formation perches the groundwater table, preventing connection to the underlying Inferior Oolite Group except where faults may provide flow paths. Springs emerging from the Great Oolite limestone and Fuller's Earth Formation boundary have the potential to recharge the Inferior Oolite limestones downgradient.

13.7.133 Recharge of the Inferior Oolite aquifer in the scheme area is from rainfall and leakage from the overlying Great Oolite aquifer via leakage through faults or from runoff over Fullers Earth Formation. However, Maurice *et al.* (2008) suggest leakage from the Great Oolite Group to the Inferior Oolite Group may only occur during the wetter months of the year when drainage from the unconfined Great Oolite Group aquifer reduces the elevation of the water table such that the saturated zone of the aquifer thins to an extent that transmissivity is greatly reduced[44].

13.7.134 Further information on aquifer recharge is presented in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

<u>Groundwater quality</u>

13.7.135 Limestone aquifers are particularly vulnerable to contamination, which may originate from point or diffuse sources. In accordance with *The Nitrate Pollution Prevention Regulations 2015*, the EA have identified areas at risk of agricultural nitrate pollution and have designated these as Nitrate Vulnerable Zones (NVZs)[45]. Waters are defined as polluted if they contain, or could contain if preventative action is not taken, nitrate concentrations greater than 50mg/L[46].

13.7.136 The EA has designated the Upper Cotswold Plateau, limestone at the crest of the Cotswold escarpment and the northern side of Crickley Hill (approximately 220m north of the scheme at Crickley Hill) as an NVZ[47].

13.7.137 Bicarbonate-rich waters are expected to be the dominant water type in the region given the presence of limestone. The geochemistry of waters in carbonate aquifers is particularly affected by residence times and mixing with recharge, older formation water and/or anthropogenic influences. Water types can typically be categorised by source, age and geological conditions including aquifer confinement.

13.7.138 Groundwaters close to recharge areas are typically oxidising and strongly pH-buffered with calcium and bicarbonate ($HCO3^-$) as dominant dissolved ions[48]. Recharge areas are particularly susceptible to high nitrate concentrations from agricultural pollution. This is anticipated to be most reflective of unconfined waters that the scheme may encounter.

13.7.139 Regionally, as groundwater becomes more confined, down gradient of recharge areas, ion-exchange processes occur, with sodium and bicarbonate being the dominant ions in the groundwater[49]. The process of ion exchange causes dissolved calcium ions in the groundwater to attach or 'absorb' onto the rock surface and, in exchange, sodium ions come off the rock surface and into the groundwater.

13.7.140 In more confined aquifers, dissolved oxygen is reduced or absent. This leads to more reducing conditions, which is evidenced by redox-sensitive elements[50]. Lower nitrate levels can suggest that denitrification may be occurring[51], however this could also be affected by mixing with old formation waters deep within the aquifer that have low nitrate levels when entering the aquifer.

13.7.141 Mixing with older formation water deeper within the confined aquifer results in a sodium-chloride type groundwater. Isotope analysis suggests a residence time in the order of thousands of years for these waters[52].

13.7.142 Neumman *et al*. (2003) concluded no significant differences in the chemistry of the Great and Inferior Oolite groundwaters can be observed[53].

13.7.143 During the Phase 1 ground investigation in February 2019, two groundwater samples were taken from the Birdlip Limestone of the Inferior Oolite aquifer (DS/RC 406) and Bridport Sand Formation (DS/RC 419). Sampling from Phase 2A boreholes was progressively completed between November 2019 and August 2020. This comprised 62 samples. An overview of the groundwater quality testing results is presented in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4) and summarised below.

13.7.144 The composition of water samples from each geological formation is relatively similar where bicarbonate waters are the most common. Generally, calcium was measured at highest concentrations, meaning that calcium is the dominant cation (positively charged particle), however some samples had higher concentrations of potassium and sodium. Samples with higher potassium and sodium concentrations were from the mass movement deposits, Inferior Oolite Group and Lias Group mudstone.

13.7.145 Water samples were typically fresh (<1,560 µS/cm), however some slightly saline to moderately saline waters were sampled from Lias Group mudstones and mass movement deposit samples. The highest EC reading was 5,600 µS/cm in DS/RC 224, located at the crest of the Crickley Hill escarpment where the Inferior Oolite Group and Lias Group mudstone are included in the response zone.

13.7.146 Exceedance of UK Drinking Water Standards occurred in the following samples:

- Sulphate as $SO_4^{2-}$ – 392mg/l in CP 104 (mass movement deposits).
- Nitrite as $NO_2$ – 1,600µg/l in DS/RC 110 (Inferior Oolite Group), 6,300 to 12,000µg/l in DS/RC 224, 750µg/l in CP 206 (mass movement deposits), 650µg/l in DS/RC 403 (Fuller's Earth Formation).

- Manganese – 27 exceedances primarily from head deposits and Inferior Oolite group samples, where the maximum recorded concentration was 1,300µg/l in CP 206.
- Sodium – 240mg/l in DS/RC 110 (Inferior Oolite Group), 260 to 270mg/l in DS/RC 224 (Lias Group mudstone and Inferior Oolite Group).
- Arsenic – 10.2µg/l in CP 200 (mass movement deposits).

13.7.147 A review of groundwater quality with respect to published Environmental Quality Standards is presented in ES Chapter 9 Geology and soils (Document Reference 6.2).

Rainfall

13.7.148 Rain gauge measurements are being undertaken to identify local relationships between rainfall, groundwater characteristics and surface water response, to understand the local hydro-geological and hydrological system.

13.7.149 The mean annual rainfall in the area is 805mm and estimated recharge is 370mm per annum[54].

13.7.150 The data from the two site-specific rainfall gauges shows the profile of the amount of rainfall at each location following a similar pattern. This data is presented in ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4).

**Existing road drainage and outfalls**

13.7.151 HADDMS identifies five priority outfalls (outfall that presents a risk of pollution[55]) within the study area for the Existing A417 network. Three of these were classed as moderate priority (category C status), one as low priority (category D status) and one as risk addressed. HADDMS notes that the medium priority outfall south of the Air Balloon roundabout and the low priority outfall may be soakaways.

13.7.152 Following a validation exercise, 58 priority drainage assets (defined as assets that, if poorly managed or inadequate, can pose a risk to safety or journey time for road users, adjacent property or the water environment56) are identified within the scheme area. Of the 58 priority drainage assets, 15 are outfalls, 25 are soakaways and 18 are culverts.

**Accidental spillage**

13.7.153 Incidents occurring on roads can cause spills of fuels and other potentially polluting substances. These spills can enter the road drainage system and consequently enter surface waters that receive highways drainage. There is also a risk of spills entering groundwater from natural infiltration. Existing highway drainage systems have no pollution control or spillage containment measures, except at Cowley junction.

13.7.154 Personal Injury Collision data on the A417 has been collected for a five year period from July 2014 to June 2019 inclusive. The data indicates that the number of incidents is equal to the national average, although there is a greater casualty rate per collision. As a result of collisions, there is potential for fuel spills and other spills of potentially polluting substances.

### Future baseline

13.7.155 As set out 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 road drainage and water environment receptors in the future would not be noticeable i.e. accidental spillage 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 the same as set out above.

### Assessment of value

13.7.156 Table 13-13 summarises the assessment of the value of water environment attributes within the study area in line with Table 13-3, and as per DMRB standards outlined in section 13.4 Assessment methodology.

**Table 13-13 Water environment receptors, attributes and value**

| Receptor | Attribute/Features | Value of Receptor | Quality |
|---|---|---|---|
| **Surface water** | | | |
| Tributary of Norman's Brook | Water supply/quantity | Medium | Watercourse not having a WFD classification shown in a RBMP, with 'Good' chemical status |
| | Conveyance of flow (presence of watercourses) | Medium | Headwater watercourse with flow of $Q_{95}$ >0.001m$^3$/s |
| | Biodiversity | High | Potential for species protected under EC or UK legislation Ecology and Nature Conservation |
| Tributary of Horsbere Brook | Water supply/quantity | Medium | Watercourse not having a WFD classification shown in a RBMP |
| | Conveyance of flow (presence of watercourses) | Medium | Headwater watercourse with flow of $Q_{95}$ >0.001m$^3$/s |
| River Frome and its tributaries | Water supply/quantity | High | Watercourse having a WFD classification ('Moderate' overall status) |
| | Conveyance of flow (presence of watercourses) | Medium | Headwater watercourse with flow of $Q_{95}$ 0.002m$^3$/s |
| Tributaries of River Churn | Water supply/quantity | Medium | Watercourse not having a WFD classification shown in a RBMP |
| | Conveyance of flow (presence of watercourses) | Medium | Headwater watercourse with flow of $Q_{95}$ 0.002m$^3$/s |
| **Groundwater** | | | |
| Superficial deposits – Secondary A aquifer | Water supply/quantity | Medium | Secondary aquifer and potential local resource |
| | Soakaway | Medium | No known discharge via soakaway; unsaturated zone thickness may be not sufficient to allow good infiltration conditions |

| Receptor | Attribute/Features | Value of Receptor | Quality |
|---|---|---|---|
| | Vulnerability | High | Aquifer vulnerability is 'High'/'Medium-high' |
| | Conveyance of flow | Low | No evidence of providing base flow to a watercourse in study area |
| | Biodiversity | Low | No GWDTEs supported by this aquifer identified in the study area |
| Lias Group – Secondary (undifferentiated) aquifer | Water supply/quantity | Low | Secondary aquifer; primarily comprising unproductive strata (mudstone) within the scheme area |
| | Soakaway | Low | Permeability of strata unlikely to allow good infiltration conditions |
| | Vulnerability | Medium | Aquifer vulnerability is 'Medium' |
| | Conveyance of flow | Low | No evidence of providing base flow to a watercourse in study area |
| | Biodiversity | Low | No GWDTEs supported by this aquifer identified in the study area |
| Inferior Oolite Group – Principal aquifer | Water supply/quantity | High | Principal aquifer and WFD waterbody; SPZ 3 and local abstraction points |
| | Soakaway | Very high | A number of discharges via soakaways present within study area; very deep unsaturated zone and bedrock properties allow for good infiltration conditions |
| | Vulnerability | High | Aquifer vulnerability is 'High' |
| | Conveyance of flow | High | Numerous springs forming headwaters of tributary of Norman's Brook and River Churn<br>Tributary of Norman's Brook:<br>Upper Crickley Hill escarpment springs and seepages (G63, G64, G65, G66, G67, G68, G73, G74, G153, G154, G187)<br>Within scheme footprint springs and seepages (61, 69, 72, 78, 80, G2, G17, G20, G151)<br>Fault springs (16, 17, 18, 19)<br>Tributary of River Churn:<br>National Start Collage area springs and seepages (G99, G97)<br>Shab Hill (G145, G146, G179, G180, G181)<br>East of Stockwell (G174, G4, G5, G6, G77) |
| | Biodiversity | Low | No GWDTEs supported by this aquifer identified in the study area |
| Great Oolite Group – Principal aquifer | Water supply/quantity | High | Principal aquifer and WFD waterbody |
| | Soakaway | Medium | One known discharge via soakaway; encountered bedrock properties variable; unsaturated zone thickness may be not sufficient to allow good infiltration conditions |
| | Vulnerability | High | Aquifer vulnerability is 'High' |

| Receptor | Attribute/Features | Value of Receptor | Quality |
|---|---|---|---|
| | Conveyance of flow | High | Numerous springs forming headwaters of River Frome and River Churn<br>Tributary of River Churn:<br>Shab Hill (G145, G146, G179, G180, G181)<br>East of Stockwell (G174, G4, G5, G6, G77)<br>Tributaries of River Frome:<br>Dry valley to the north of the watercourse (G143, G150, G147, G173)<br>Eastern valley side (G100, G219, G223, G222)<br>Western valley side (Bushley Muzzard SSSI springs G102, G25) |
| | Biodiversity | High | Supports Bushley Muzzard SSSI and GWDTE |

## 13.8 Potential impacts

13.8.1 The scheme has the potential to impact the water environment during construction and operation.

13.8.2 This section describes the potential impacts considered during the assessment, based on consultation with the regulators, the scheme's design team and professional judgment.

13.8.3 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 13.9 Design, mitigation and enhancement measures. Prior to the implementation of mitigation, the scheme has the potential to affect road drainage and the water environment during construction and operation, both beneficially and adversely.

### Construction

13.8.4 During construction, the potential impacts surface water features, groundwater features and flood risk could arise from:

- Impacts on water quality from mobilised suspended solids and spillage of fuels or other harmful substances e.g. cement that may migrate to surface water and groundwater receptors.
- Impacts to the hydromorphological and ecological quality of watercourses associated with works within or in close proximity to watercourses, including physical change to the watercourses and longer-term changes associated with sediment deposition.
- Impacts to local land drainage structures, that may alter existing drainage patterns within catchments and provide potential pathways for pollution.
- Impacts on local hydrogeology and groundwater resources through changes to groundwater levels, flows and quality arising from construction activities, primarily dewatering, construction of cuttings or shallow earthworks, ground stabilisation measures and intrusive ground investigation creating new flow paths for groundwater.

13.8.5 Further details of potential impacts are provided in the following sections.

Surface water impacts

*Surface water quantity*

13.8.6 The creation of a drain may divert water from one surface water catchment to another (between local surface water catchments within the Severn catchment, and between the Severn and Thames catchments). This interruption of flow may lead to a reduction or loss of water supply to abstractions, springs and watercourses and potential loss of habitat (which may be permanent). The loss of water from one catchment to another potentially affects resource availability further down-gradient in the confined aquifers. Based on the proposed drainage strategy, this may occur in the area of the cutting between Ch. 2+200 and Ch. 3+000, where the highway drainage would divert water flows from the Thames catchment to the Severn catchment. Equally repurposing the Existing A417 would provide an opportunity to return some land into the Severn catchment by removal of the highway drainage and allowing water infiltration into the ground.

13.8.7 Embankments and earth bunds could create a barrier for springs currently recharging to the surface watercourses and redirection of flows to a different catchment, ultimately reducing catchment areas of the River Churn and the River Frome and changing the flow regime within these surface waters. This may also have consequential effects on aquatic ecology.

13.8.8 Construction of the earth bunding alongside the widening of the A417 along Crickley Hill would result in the diversion of the tributary of Norman’s Brook, potentially into a watercourse elevated in relation to the current watercourse alignment. This may result in springs currently issuing into the watercourse infiltrating the proposed embankment and consequently reducing flows within the watercourse.

13.8.9 The Shab Hill junction is located within a dry valley. One seepage from the head deposits is located within the dry valley which will be covered by the embankment. The embankment could impact flows to Coldwell Bottom and the River Churn.

13.8.10 The realignment of the tributary of Norman’s Brook would result in the loss of the existing water course and would introduce new water levels for the watercourse.

13.8.11 The construction of cuttings and treatment of any voids (e.g. large fissures, gulls) encountered may result in blockage of preferential flow paths within the rock mass. This could impact upon water resource availability for springs and baseflow.

13.8.12 Construction works may locally reduce the rate of recharge to aquifers where the runoff is managed and then discharged. This has the potential to reduce flow of springs, watercourses and groundwater abstractions.

*Surface water quality*

13.8.13 Working in, on or adjacent to watercourses may affect surface water quality through the accidental discharge of sediments or chemicals, including hydrocarbons. There may also be impacts to channel form through plant movements and operations.

13.8.14 Where works would require groundwater control measures e.g. local groundwater level reduction or removal of the water from the excavation (dewatering), the discharge of removed groundwater into surface watercourses may affect the quality of the receiving watercourses, primarily through sediment release but also if the removed groundwater is contaminated.

*Hydromorphology*

13.8.15 Physical change to watercourses and longer-term changes associated with sediment deposition are likely to have impacts on the hydromorphological and ecological quality of watercourses.

13.8.16 The realignment of the tributary of Norman's Brook would result in the permanent loss of this hydromorphological feature. The works would also result in the loss of geomorphological features and habitat niches within the channel.

13.8.17 The realignment of the tributary of Norman's Brook may also result in the loss of geological features including tufa formations, which may also be of ecological importance in the area, and locally change the groundwater regime that feeds springs and baseflow in the vicinity. Potential ecological impacts are assessed in ES Chapter 8 Biodiversity (Document Reference 6.2). Potential geological impacts are assessed in ES Chapter 9 Geology and soils (Document Reference 6.2).

Groundwater impacts

*Groundwater levels and flows*

13.8.18 ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4) identifies that the cutting spanning Ch. 1+700 to Ch. 3+000 and cuttings between Shab Hill junction and Cowley junction (Ch. 3+200 to Ch. 5+000) have the potential to intersect groundwater levels during peak winter events but that during the summer groundwater levels will remain below the cutting inverts. On this basis dewatering will be required if construction is undertaken during the winter but is unlikely to be needed during the summer.

13.8.19 Where works would require groundwater control measures e.g. local groundwater level reduction or removal of the water from the excavation (dewatering), this could locally reduce groundwater levels and divert flow. This risk would depend on the time of year as flows and levels would vary in an aquifer of this nature. This water may also be connected to spring systems which feed into local watercourse baseflows. The impact on groundwater resources would be local to the excavation and last for the duration of the works only.

13.8.20 Dewatering zone of influence may extend into the outer area of SPZ3 for the Baunton abstraction. However, the Baunton abstraction takes water from the Inferior Oolite Group aquifer. The cuttings between Shab Hill junction and Cowley junction (Ch. 3+200 to Ch. 5+000) are within the Great Oolite Group and therefore dewatering would not impact the abstraction.

13.8.21 Dewatering, if required, to allow stabilisation of the landslip material on Crickley Hill could affect flow to springs rising from the escarpment, although the water would be returned to the tributary of Norman's Brook at the toe of the landslip.

13.8.22 These construction activities may lead to a reduction or cessation of spring flow and baseflow supplying watercourses within the Norman's Brook, Frome and Churn catchments, as well as adversely impacting on groundwater resources/abstractions during winter periods.

13.8.23 The scheme comprises structures such as overbridges and underbridges. The conceptual structures foundation design indicates that the structures would be founded on deep piled foundations, usually consisting of individual piles, sometimes constructed in groups of two or more. This kind of foundation would require a pile cap, a shallow concrete structure placed at or near ground level, providing protection to the inserted piles. Such below ground structures may act as barriers to shallow groundwater flow and they may provide more vertical downward pathways for perched/shallow groundwater flow into the deeper aquifer. Contamination migration as a result of the scheme is considered in ES Chapter 9 Geology and soils (Document Reference 6.2).

13.8.24 These underground structures may cause local changes to groundwater flow and mounding of groundwater on the up-gradient side of the structure (raised groundwater levels on the up-gradient side with potentially reduced groundwater levels on the down-gradient side) causing creation or reactivation of springs or even induce groundwater flooding. This could have an impact on springs, watercourses, groundwater-dependent habitats and abstractions, where flow could be reduced or temporarily ceased. Considering the structures as part of the scheme and the extent of the below ground foundation works associated with these structures, these impacts are likely to be localised.

13.8.25 Deep foundations such as piling may create pathways through relatively low permeability formations, such as the Fuller's Earth Formation, and connect the Great Oolite Group and Inferior Oolite Group aquifers. Deep foundations that intercept faults zones, which act as a flow barrier, may connect previously disconnected strata and groundwater bodies with dissimilar qualities. New flow paths for pollution may also be created and allow polluted waters to enter water bodies not previously impacted by pollution. As discussed, the impact of any new flow paths that may be created is expected to be not significant on a regional scale as leakage via faulting is noted throughout the region. There may be localised impacts upon the water quality within the aquifers.

13.8.26 Changes to groundwater regime may also impact cultural heritage that is currently preserved in waterlogged deposits, as considered in ES Chapter 6 Cultural heritage (Document Reference 6.2).

*Groundwater quality*

13.8.27 Where works would require groundwater control measures e.g. local groundwater level reduction or removal of the water from the excavation (dewatering), this could locally reduce groundwater levels and divert flow. Discharge of removed groundwater into surface watercourses may affect the quality of the receiving watercourses, primarily through sediment release but also if the removed groundwater is contaminated.

13.8.28 Ground investigation boreholes may create pathways through relatively low permeability formations, such as the Fuller's Earth Formation, and connect the Great Oolite Group limestone and Inferior Oolite Group. New flow pathways for pollution may also be created, allowing polluted waters to enter water bodies not previously impacted by pollution. There may be localised effects upon water quality within the aquifers.

*GWDTE*

13.8.29 The scheme could impact on the hydrological and hydrogeological regimes and consequently affect GWDTEs during construction, particularly Bushley Muzzard SSSI.

13.8.30 The impacts on tufa habitats are considered in ES Chapter 8 Biodiversity (Document Reference 6.2).

Accidental spillage

13.8.31 Stockpiling of construction materials and excavated spoil may contaminate or pollute groundwaters if they are not stored correctly. These contaminants and pollutants may include fuels, oils, chemicals and concrete. This has the potential to impact the water quality of surface waters, aquifers, springs, abstractions and groundwater-dependent habitats indirectly via site runoff or directly where works are close to and within a water body. The flashy response of the limestone aquifers may exacerbate the extent of pollution and make it hard to contain. This is a concern in relation to the Baunton SPZ3.

13.8.32 Introduction of wet concrete and grout into the fissures of the Inferior Oolite Group or as part of soil nailing in the Crickley Hill escarpment landslip area have the potential to impact upon groundwater quality due to its inherently high pH and the potential to migrate. This would impact upon the water quality of the aquifer, springs, watercourse base flows and groundwater-dependent habitats.

13.8.33 Removal of topsoil or hardstanding and exposure of underlying soils to increased rainwater infiltration may result in pollutants leaching into the underlying aquifer.

13.8.34 Drainage for construction works may also distribute contaminants and pollutants to other parts of the aquifer and create an accumulation of these substances where soakaway basins are used.

Flood risk

13.8.35 Any construction works on drainage to watercourses or to ground have the potential to increase the rate and volume of runoff and increase the risk of blockages in watercourses that could lead to flow being impeded, and a potential rise in flood risk. Changes to ground levels, temporary increases in impermeable area and vegetation clearance works may also increase the risk of surface water flooding. Finally, excavations can potential damage existing sewers leading to flooding.

**Operation**

13.8.36 During operation, potential impacts to surface water features, groundwater features and flood risk could arise from:

- Polluted surface water runoff containing silts and hydrocarbons that may migrate or be discharged to surface water features or groundwater resources via the highway drainage system, including from spillages.

- Permanent impact to the hydromorphological and ecological quality of water features associated with works within or in close proximity to water features.
- Permanent impacts to catchment hydrology and hydrogeology caused by the introduction of a barrier to natural overland flow e.g. introduction of embankments or below ground structures, and changes to natural catchment dynamics associated with the highway drainage system.
- Permanent impacts to catchment hydrology and hydrogeology caused by impact to natural groundwater springs or groundwater flow associated with drainage in road cuttings that could affect baseflow to watercourses and groundwater resources.
- Increased rates and volumes of surface water runoff from an increase in impermeable area or changes to the existing drainage regime leading to a potential increase in flood risk.
- Increased flood risk to the scheme and to people and property elsewhere caused by crossing of watercourses thus affecting flood flow conveyance or works in floodplains reducing holding capacity.
- Change in the rate of recharge of aquifers due to change in ground surface cover and introduction of new drainage systems.
- Permanent impact to groundwater quality from removal of consented sewage discharge into the ground.
- Reduced dilution and/or dispersion of consented discharges to groundwater and treated sewage effluent due to reduced or redirected groundwater flow paths.

13.8.37 There is limited information regarding the existing road drainage arrangements and water treatment provision. The scheme may provide an opportunity to provide betterment.

13.8.38 Further details on potential impacts are provided in the following sections.

<u>Surface water impacts</u>

*Surface water quantity*

13.8.39 Alteration of ground elevations and changes in surface water flood flow pathways may result in the overloading of drainage systems and/or surface watercourses. This may impact on flood-sensitive receptors near to overloaded systems.

13.8.40 Wherever possible, the design will maintain existing catchments. Surface water from land south-west of the scheme’s cutting between the Air Balloon roundabout and Shab Hill junction currently flows to the River Churn catchment via dry valleys at Leckhampton Hill and Ullenwood, which converge at the National Star College golf course.

13.8.41 As a result of the scheme there would be a net increase of up to 23ha in the catchment area to the tributary of Norman’s Brook and a corresponding reduction in the catchment area to the River Churn.

13.8.42 This includes 16ha of hillside at Emma’s Grove which is part of the tributary of Norman’s Brook catchment (see ES Figure 13.3 WFD Surface waterbodies (Document Reference 6.3)). However, run-off from this area is actually intercepted by the Existing A417 Birdlip Hill cutting and collected in the highway drainage systems.

13.8.43 These systems rely partially upon infiltration, but in exceedance events currently flow to the River Churn catchment. The scheme would return the catchments to a situation closer to the natural delineation that existed before the A417 Birdlip Bypass scheme was constructed (1987).

13.8.44 An increase in the rate and volume of surface water runoff to surface watercourses may impact on properties and aquatic environments near to flood zones.

*Surface water quality*

13.8.45 Road drainage discharge of routine runoff to outfalls, or soakaways if required, may cause long-term degradation of water quality. Discharge of runoff containing silts and hydrocarbons during accidental spills or collisions, may have an impact on water quality.

13.8.46 The pollution of surface watercourses may result in potential loss of aquatic habitat. This may, in turn, result in impacts on the amenity and economic value of surface water bodies.

*Hydromorphology*

13.8.47 Four new culverts are proposed to enable the proposed highway to cross existing watercourses (Table 13-4). None of these watercourses are designated as main rivers. In addition to these culverts, there would be numerous smaller culverts conveying flows from the cut-off ditches under tracks and private accesses.

**Table 13-14 New culverts proposed as part of the scheme**

| Receptor (Chainage (m)) | Size and description |
|---|---|
| Tributary of Norman's Brook at Crickley Hill Stream Culvert<br>(0+530) | 0.6 metre diameter (as existing).<br>190 metre length (~55 metre existing) |
| Tributary of Norman's Brook<br>(1+450)<br>Grove Farm Culvert | 1.2 metre diameter.<br>320 metre length. |
| Tributary of River Churn at Shab Hill Culvert (3+200) | 1.2 metre to account for dry valley. |
| Tributary of River Churn at Stockwell Culvert (4+775) | 1.2 metre to account for dry valley. |

13.8.48 Culverts have the potential to affect watercourses by causing local shading, reducing river habitat connectivity and inducing hydromorphological change.

13.8.49 New outfalls would be installed to discharge treated carriageway runoff from the drainage system to surface watercourses. The discharges would be limited to the greenfield runoff rate, where infiltration is not possible, and would be located near to the proposed drainage basins.

13.8.50 New outfall structures within a watercourse can alter local channel cross section and induce local bank or bed erosion, as well as reduce the available natural bank habitat area. These potential effects can be reduced by ensuring that outfall structures are sensitively designed based on the mitigation proposed.

13.8.51 An interruption of flow in the watercourse may result in a reduction or loss of water supply to downstream receptors, including abstractions, rivers and wetlands, and the potential loss of aquatic habitat (which may be permanent).

Groundwater impacts

*Groundwater quality*

13.8.52 The scheme would result in the removal of two known sewage discharge soakaways, one associated with the existing Air Balloon public house (a consented discharge) and one associated with the Birdlip radio station (an unconsented discharge). Both are currently discharging to the ground and consequently groundwater. The Air Balloon public house would be demolished and therefore the sewage discharge would cease. The Birdlip radio station would be equipped with a new cesspit. These would lead to the betterment of groundwater quality as the discharges of sewage would cease leading to a beneficial impact.

13.8.53 The infiltration of road runoff to groundwater could impact on groundwater quality at all discharge locations.

*Groundwater level and flow*

13.8.54 The cutting spanning Ch. 1+700 to Ch. 3+000 and cuttings between Shab Hill junction and Cowley junction (Ch. 3+200 to Ch. 5+000) may create a localised reduction of groundwater levels, leading to a reduction or cessation of local spring flow. This may result in the depletion of existing watercourses and loss of water supply to groundwater receptors, including springs, watercourses and abstractions.

13.8.55 The level groundwater table lies lower than cutting levels in the summer, but winter seasonal peaks may be intercepted by cutting invert levels. Groundwater flow intercepted during winter peaks may reduce the quantity of peak groundwater flow and peak spring flows.

*GWDTE*

13.8.56 The scheme could impact on the hydrological and hydrogeological regimes and consequently affect GWDTEs during operation, particularly Bushley Muzzard SSSI.

13.8.57 The impacts on tufa habitats are considered in ES Chapter 8 Biodiversity (Document Reference 6.2).

Accidental spillage

13.8.58 Discharges via soakaways could lead to direct pollution of a strategically important aquifer underlying the scheme. Discharges directly to surface watercourses could lead to direct pollution of receiving watercourses.

Flooding

13.8.59 A change in the flood flow pathway may impact on properties and aquatic environments close to flood zones. In particular, the realignment of the tributary of

Norman's Brook may result in flooding further upstream and downstream without appropriate mitigation to attenuate flows.

Climate change

13.8.60 ES Chapter 14 Climate (Document Reference 6.2) follows the methodology set out in LA 114 *Climate* and considers the effects related to climate change as per the requirements of the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017. The assessment of effects considers the combined impacts of the scheme and potential climate changes on the receiving environment during construction and operation.

13.8.61 Future climate conditions derived from the UK Climate Projections 2018 (UKCP18) indicates that the study area may undergo climatic changes including higher temperatures, increase in heat waves, reduced precipitation in summer and increased precipitation in winter.

13.8.62 Surface water flows are likely to become more variable, with more frequent extremes including wetter winters and drier summers.

13.8.63 Increasing long spells of hot weather and wildfires may result in soils developing temporary water repellence, which may reduce or temporarily impede water infiltration, leading to preferential flow and increased surface runoff.

13.8.64 These conditions are likely to reduce the amount of recharge to the groundwater, which may have impacts upon features in the study area and cause some perennial features to become ephemeral. Abstractions, springs, groundwater-fed watercourses, areas of flooded ground and Bushley Muzzard SSSI are likely to be particularly sensitive to these impacts. Groundwater quality is also likely to be affected by a reduction in the flushing of aquifers, which may increase the residence time of groundwater within them.

13.8.65 Intensive rainfall may reactivate springs flows to cuttings or in dry valleys leading to drainage system overload and consequently result in flooding.

13.8.66 While the impacts of climate change are likely to affect the water environment, no significant effects are predicted as a result of the incorporation of embedded mitigation in the scheme design, such as the scheme's drainage having been designed for the latest climate change allowances, as identified in ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4).

13.8.67 Climate change is considered for the scheme in ES Chapter 14 Climate (Document Reference 6.2).

## 13.9 Design, mitigation and enhancement measures

### Embedded design mitigation

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

13.9.2 Details of the scheme's drainage design are presented in ES Appendix 13.10 Drainage Report (Document Reference 6.4) and displayed on ES Figure 13.19 Scheme Highway Drainage (Document Reference 6.3). Details of the treatment trains for each area of road drainage are included in ES Appendix 13.4 Water Quality Assessment (Document Reference 6.4).

### Construction mitigation

13.9.3 Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4) includes measures that are considered as standard good practice that would be implemented by the construction contractor to reduce the likelihood of effects or their magnitude if they were to occur. It also contains the outline ground and surface water monitoring plans.

13.9.4 The standard measures included in ES Appendix 2.1 EMP (Document Reference 6.4) are based on the EA's PPGs (withdrawn in 2015), subsequent guidance on GOV.UK, the relevant CIRIA publications and best practice measures outlined in the GPPs.

13.9.5 Examples of standard practice mitigation measures included in ES Appendix 2.1 EMP (Document Reference 6.4) include the provision of spill kits, restricting site traffic to dedicated haul roads and ensuring hard-standing areas are regularly swept and maintained.

13.9.6 Effective delivery of the measures set out in ES Appendix 2.1 EMP (Document Reference 6.4) would be monitored during the construction phase.

Surface water management

13.9.7 Site-specific measures to manage surface water include a surface water management system using measures such as temporary silt fencing, cut-off ditches, settlement ponds and bunds set up early in the construction period to capture all runoff and prevent ingress of sediments and contaminants into existing drainage ditches where necessary. This would be managed by the EMP (ES Appendix 2.1 EMP (Document Reference 6.4)) in accordance with CIRIA guidelines and the EA's approach to groundwater protection[57] and groundwater protection guidelines[58]. All works close to watercourses should be carefully designed and supervised.

13.9.8 Areas of exposed soils deemed at risk of erosion during heavy rainfall or flood inundation would be protected using either temporary measures (e.g. sheeting) or semi-permanent measures (for example coir matting) until vegetation is able to establish on these surfaces. Further measures on the storage and management of soils are included in ES Chapter 9 Geology and soils (Document Reference 6.2).

13.9.9 Works would be suspended during out-of-bank river flows or during intense rainstorms.

13.9.10 Water with a higher risk of contamination which requires discharge, including groundwater pumped out of pilings during concrete pouring, would be contained and treated using appropriate measures such as coagulation of sediments, dewatering and pH neutralisation prior to discharge. Such discharges would be regulated via environment permits issued by the EA.

13.9.11 The impacts on flows arriving at the tributary of Norman's Brook would be mitigated by:

- The removal of paved areas within the catchment along the old A417 Birdlip Hill cutting between the Air Balloon and Barrow Wake.
- The introduction of infiltration and storage features within the old A417 Birdlip Hill cutting.
- The provision of attenuation storage within the perimeter land drainage ditches along the south side of the Crickley Hill cutting.
- The removal of paved areas from the old A417 at Crickley Hill between Bentham Lane and the Air Balloon roundabout, and their replacement with new highway drainage systems attenuated to greenfield run off rates.

Water quality management and tracer testing

13.9.12 A water quality monitoring programme prior to and during construction works will be agreed with EA.

13.9.13 Tracer testing would be used to identify and confirm groundwater flow paths and surface water interactions. Additional tracer tests and hydraulic testing may be required to confirm hydraulic connectivity and properties of surface waters and groundwater bodies, and further define sub-catchments.

Drainage basin design

13.9.14 LA 113 states that where a medium risk of impact is indicated, detailed assessment is undertaken by a competent expert. Detailed assessment of risks posed by routine runoff to groundwater quality would be completed at detailed design when infiltration rate through the ground and ground conditions specific to the basin locations would be obtained. Baseline groundwater level and quality monitoring is still ongoing and will also inform the assessments.

13.9.15 The specific mitigation measures required in the design of drainage systems and basins would be refined at detailed design. This could include measures to separate carriageway drainage systems from groundwater, the lining of basins, and limitations on the disposal of surface water though infiltration.

13.9.16 The assessment would be specific to a locale of the point of discharge, which is not relevant to the wider groundwater body due to dilution effects. Depending on complexity and site-specific characteristics the assessment would follow a regulatory guidance on hydrogeological risk assessment for land contamination methodology [59] with associated worksheet[60,61]or a probabilistic modelling software package, ConSim[62]. Where required, the detailed assessment will incorporate mitigation measures to reduce the risk to a suitable level.

Watercourse realignment (tributary of Normans Brook)

13.9.17 Appropriate sequencing and domaining of works, such as the tributary of Norman's Brook realignment, to reduce impacts to surface and groundwater flows to be temporarily diverted downstream of the works area.

13.9.18 Potential adverse effects upon hydromorphology from new culverts and outfalls would be suitably mitigated by following the guidance in DMRB CD 529 Design of outfall and culvert details during detailed design.

13.9.19 The potential for adverse effect upon the hydromorphology of the tributary of Normans Brook as a result of the loss of up to 320m of open watercourse and the realignment of a further 850m of watercourse would be mitigated by:

- The detailed design of the realigned watercourse would provide naturalistic features of an equivalent or greater value to that of the existing watercourse. The scheme would aim to replicate the character and geomorphology of a typical upland stream, and there would be space within the 5m wide platform to accommodate features such as step pools, cascades, informal steps and irregular meanders.
- The realigned stream would minimise the introduction of new culverted sections, wherever possible.
- The flow regime of the realigned watercourse would be as similar as the existing flow regime as practicable.
- The detailed design should be overseen by an experienced fluvial geomorphologist.

Management of dewatering activities

13.9.20 Consideration of local groundwater catchment and flow regimes that may be affected by dewatering design and discharging the abstracted water to the same groundwater catchment and down gradient of the dewatered element.

13.9.21 Discharge from dewatering activities such as earthworks, works within a floodplain or within eight metres of a watercourse would have a tailored risk assessment, consent and licences from the EA. Dewatering abstractions may also require transfer licenses from the EA. These will be informed by site specific hydrogeological assessments completed at detailed design as further site-specific information is received. Discharge consents may also be required.

13.9.22 Grouting may be required to treat voids encountered during earthworks. Furthermore, cutting and slope stabilisation works may involve the use of soil nails, rock anchors and/or rock bolts, all of which involve the use of typically steel reinforcing elements drilled and grouted into the slopes or cutting faces. Grout is usually injected under pressure through the centre of hollow threaded steel reinforcement bars in order to completely fill the annulus between the bar and the surrounding ground. It is not readily possible to prevent grout from entering fissures or voids should they be present within the rock mass being stabilised. Appropriate grouting methodologies would be adopted to reduce any risks to the water environment. This would include limitation of grout volumes, use of high viscosity grout, monitoring for pH spikes in monitoring standpipes/surface flows. The use of polymer grouts would be proposed in the event that such control measures are not practical to control risks associated with conventional cementitious grout. The results of intrusive and geophysical investigations, and tracer tests where available, would be considered when developing design solutions which may require the use of grout.

Underground structures

13.9.23 A site-specific foundation works risk assessment (FWRA) for the construction of underground structures and ground improvement works would be conducted. This will be shared with the EA for consultation. This is also required with respect to land contamination risk management (ES Chapter 9 Geology and soils (Document Reference 6.2)).

13.9.24 Design of underground structures would require drainage provisions to relieve hydrostatic pressure. These would allow for groundwater flow around the structure.

### Operation mitigation

13.9.25 Operation embedded mitigation is described in detail in ES Chapter 2 The project (Document Reference 6.2).

### Essential mitigation

13.9.26 Essential mitigation to address likely significant effects includes:

- Should ground investigations undertaken in detailed design identify localised flow regimes associated with the tributary of Norman's Brook, mitigation would be developed to maintain these flows during construction.
- Drainage design to incorporate feasible treatment, or where this is not possible, no infiltration would be permitted.
- Design of stabilisation (essential) mitigation measures to discharge captured groundwater into the realigned tributary of Norman's Brook therefore maintaining the net water balance within the catchment.
- Development of voids protocol setting out procedures and measures allowing for treatment of voids that would reduce impact on groundwater flows.
- Detailed drainage design would retain the recharge of flows in the tributary of Norman's Brook and the unnamed tributary of River Frome.
- Further detailed modelling on residual flood risk and following of the scheme and the design of the realignment of the tributary of Norman's Brook, to ensure that flood risk does not increase as a result of the scheme. The detailed design of the tributary of Norman's Brook and the drainage system in this area, to control peaks to the inlet of Crickley Hill stream culvert, would be undertaken to improve the resilience of the area. Further modelling would be undertaken in the detailed design phase of the scheme.

13.9.27 These measures are included in Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4) and secured by a requirement of the DCO. These measures are also reported in the Register of Environmental Actions and Commitments in ES Appendix 2.1 EMP (Document Reference 6.4).

### Enhancement

13.9.28 The realigned tributary of Norman's Brook will be designed to cater for the ecological requirements of aquatic species present in the tributary of Norman's Brook. The barriers (man-made weirs) currently present within the tributary of Norman's Brook would not be recreated in the new channel, which would be characterised by step-pool habitat, typical of higher gradient headwater streams. The new channel would improve connectivity of habitat for aquatic species. Further details are included in ES Chapter 8 Biodiversity (Document Reference 6.2).

13.9.29 The scheme will comprise a road drainage scheme that will capture pollutants within road run-off and remove pollutants before the treated run-off is discharged. The scheme is will provide a betterment on the existing road drainage system and improve the water quality of receiving waterbodies.

13.9.30 There will be additional enhancements from the removal and/or upgrading of existing foul drainage outfalls to surface water and groundwaters at various properties, including Air Balloon public house and Glass House (at Grove Farm).

## 13.10 Assessment of likely significant effects

13.10.1 This section presents the assessment of likely significant effects on road drainage and the water environment resulting from the construction and operation of the scheme.

13.10.2 The assessment of effects considers the potential impacts to each receptor following the implementation of embedded and essential mitigation measures to determine the significance of the residual effects

13.10.3 The assessment of effects has been undertaken based on a reasonable worst-case scenario.

13.10.4 For effects on groundwater and groundwater-dependent features this scenario has been presented within ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4). Due to a large proportion of the surface water features being groundwater derived, the outcomes from the reasonable worst-case scenario presented in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4) have been used as the basis of the full range of surface water sub-topics.

13.10.5 The effects of the scheme on WFD quality elements is discussed in greater detail in ES Appendix 13.2 WFD Compliance Assessment (Document Reference 6.4).

13.10.6 A summary of the assessment is included in the following sections, considering the potential impacts outlined in section 13.8 and provides a narrative to the assessment.

13.10.7 Complete details of non-significant effects are presented in ES Appendix 13.9 Non-significant effects (Document Reference 6.4).

**Construction effects**

<u>Surface water</u>

*Surface water quantity*

13.10.8 The scheme alignment generally traverses the watershed between the River Severn and Thames catchments, to the west and east, respectively. Several springs emerge along the flanks of this watershed boundary, flowing to the west and east and, as such, there are some areas of interaction with cuttings and earthworks associated with the scheme.

13.10.9 Impacts include modifications to the hydrology of watercourses resulting from cutting or embankment drainage. This is due to local changes in groundwater flows or levels, potentially impacting the springs feeding the watercourses.

*Tributary of Norman's Brook*

13.10.10 Given the potential changes in hydrology as a result of construction of the Crickley Hill earth bund, drainage associated with slope stability measures and Cotswolds Way overbridge foundations upon baseflows of watercourses, minimal changes to the flow regime of the tributary of Norman's Brook is anticipated.

13.10.11 Design of embedded mitigation measures through detailed drainage design and adherence to Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4) would the minimise the diversion of flow from springs away from the watercourse and retain recharge of baseflows as a result of Crickley Hill earth bund during construction for the tributary of Norman's Brook. Following embedded and essential mitigation, the magnitude is considered to be negligible.

13.10.12 Design of cutting or structure drainage will maintain flow directions and existing catchment areas wherever possible reducing the impact on surface water quantity for the tributary of Norman's Brook. In addition, detailed assessment of groundwater-surface water interaction during detailed design and adherence to Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4) would retain the recharge of baseflows as a result of drainage associated with slope stability measures and Cotswolds Way overbridge foundations during construction for the tributary of Norman's Brook. Following embedded and essential mitigation, the magnitude is considered to be negligible.

13.10.13 Should ground investigations undertaken in detailed design identify localised flow regimes, mitigation would be developed to maintain these flows during construction.

13.10.14 With the sensitivity of the receptor being high, and magnitude of impacts of negligible, the effect would be slight adverse and not significant.

*Unnamed tributaries of River Churn*

13.10.15 Given the potential changes in hydrology as a result of construction of the scheme upon baseflows of watercourses from Shab Hill embankment, cuttings between Ch. 1+700 to 3+000, Shab Hill cutting (3+000 to 3+200) and cuttings between Shab Hill junction and Cowley junction (Ch. 3+200 to Ch. 4+200), minimal changes to the flow regimes on the unnamed tributaries of the River Churn are anticipated.

13.10.16 Design of embedded mitigation measures through detailed drainage design and adherence to Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4) would retain the recharge of baseflows as a result of the Shab Hill embankment and Cowley junction embankment during construction for unnamed tributaries of the River Churn. Following embedded and essential mitigation, the magnitude is considered to be negligible.

13.10.17 Design of cutting or structure drainage will maintain flow directions and existing catchment areas wherever possible reducing the impact on surface water quantity for the unnamed tributaries of the River Churn. In addition, detailed assessment of groundwater-surface water interaction during detailed design and adherence to Annex G Ground and surface water management plan of ES Appendix 2.1 EMP

(Document Reference 6.4) would retain the recharge of baseflows as a result of cuttings between Ch. 1+700 to 3+000, Shab Hill cutting (3+000 to 3+200), cuttings between Shab Hill junction and Cowley junction (Ch. 3+200 to Ch. 4+200) and overbridges piled foundation.

13.10.18 Should ground investigations undertaken in detailed design identify localised flow regimes, mitigation would be developed to maintain these flows during construction.

13.10.19 With the sensitivity of the receptor being medium, and a magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Unnamed tributary of River Frome*

13.10.20 Given the potential changes in hydrology as a result of construction of the scheme upon baseflows of watercourses from Stockwell-Nettleton embankment, cuttings between Shab Hill junction and Cowley junction (Ch. 4+200 to Ch. 5+000) and Stockwell-Nettleton overbridge piled foundations, minimal changes to the flow regimes on the unnamed tributary of the River Frome is anticipated.

13.10.21 Design of embedded mitigation measures through detailed drainage design and adherence to Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4) would retain the recharge of baseflows as a result of Stockwell-Nettleton embankment during construction for unnamed tributary of the River Frome. Following embedded and essential mitigation, the magnitude is considered to be negligible.

13.10.22 Design of cutting or structure drainage will maintain flow directions and existing catchment areas wherever possible reducing the impact on surface water quantity for the unnamed tributary of the River Frome. In addition, detailed assessment of groundwater-surface water interaction during detailed design and adherence to Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4) would retain the recharge of baseflows as a result of cuttings between Shab Hill junction and Cowley junction (Ch. 4+200 to Ch. 5+000) and Stockwell-Nettleton overbridge piled foundations.

13.10.23 Should ground investigations undertaken in detailed design identify localised flow regimes, mitigation would be developed to maintain these flows during construction.

13.10.24 With the sensitivity of the receptor being high, and a magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Unnamed tributary of Horsbere Brook*

13.10.25 Given the potential changes in hydrology as a result of construction of the scheme upon baseflows of watercourses minimal changes to the flow regime of the unnamed tributary of the Horsbere Brook as a result of structures including a drainage basin are anticipated.

13.10.26 Design of embedded mitigation measures through detailed drainage design would retain the recharge of baseflows as a result of cuttings and structures during construction in the tributary of River Frome. Following embedded and essential mitigation, the magnitude is considered to be negligible.

13.10.27 With the sensitivity of the receptor being medium, and a magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Surface water quality*

*Tributary of Norman's Brook*

13.10.28 Following the implementation of mitigation listed in Annex G Ground and surface water management plan Ground and surface water management plan of Appendix 2.1 EMP (Document Reference 6.4), the magnitude of a pollution incident as a consequence of the construction of the scheme on the tributary of Norman's Brook is likely to be negligible.

13.10.29 With the sensitivity of the receptor being high, and a magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Unnamed tributaries of River Churn*

13.10.30 Following the implementation of mitigation listed in Annex G Ground and surface water management plan of Appendix 2.1 EMP (Document Reference 6.4), the magnitude of a pollution incident as a consequence of the construction of the scheme on the unnamed tributaries of the River Churn is likely to be negligible.

13.10.31 With the sensitivity of the receptor being medium, and a magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Unnamed tributary of River Frome*

13.10.32 Following the implementation of mitigation listed in Annex G Ground and surface water management plan of Appendix 2.1 EMP (Document Reference 6.4), the magnitude of a pollution incident as a consequence of the construction of the scheme on the unnamed tributary of the River Frome is likely to be negligible.

13.10.33 With the sensitivity of the receptor being high, and a magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Unnamed tributary of Horsbere Brook*

13.10.34 Following the implementation of mitigation listed in Annex G Ground and surface water management plan of Appendix 2.1 EMP (Document Reference 6.4), the magnitude of a pollution incident as a consequence of the construction of the scheme on the unnamed tributary of Horsbere Brook is likely to be negligible.

13.10.35 With the sensitivity of the receptor being medium, and a magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Hydromorphology*

*Tributary of Norman's Brook*

13.10.36 The widening of the A417 and the earth bund along Crickley Hill requires the tributary of Norman's Brook to be realigned. The realignment of the watercourse would impact upon channel morphology and may also impact upon flows within the watercourse by limiting the ability of the realigned watercourse to receive water from existing springs due to its raised bed level. ES Appendix 13.5

Hydromorphology Assessment (Document Reference 6.4) identifies and assesses the potential effects upon hydromorphology.

13.10.37 There would also be an adverse effect upon hydromorphology as a result of the temporary loss of the tributary of Norman's Brook through the construction period. This impact would be localised to the 1.1km section of watercourse from the existing culvert beneath the A417 to the spring at the head of the watercourse. Mitigation of this effect is unlikely to be feasible given the constraints on the construction area. Opportunities for enhancement of the realigned channel would be sought to provide net benefit in the long term (see section 13.9.28).

13.10.38 With the sensitivity of the receptor being high, and a magnitude of impact of moderate adverse, the effect would be moderate adverse and significant. As the loss is temporary, a significance of effect for the loss of the tributary of Norman's Brook during construction is considered to be moderate adverse, and significant.

Groundwater

*Groundwater levels and flows*

13.10.39 The assessment of potential impacts on groundwater levels resulting from the proposed drainage intercepting groundwater (i.e. in cuttings or associated with slope stability) is presented in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4) and graphically presented in ES Figure 13.16 Groundwater impact assessment (Document Reference 6.3).

13.10.40 The construction of embankments along the tributary of Norman's Brook and in Shab Hill area will also impact the springs and seepages located within the footprint of the works. In addition, the construction of piled foundations for the crossings and overbridges may locally impact the groundwater flows.

13.10.41 The potential effects upon some groundwater features identified along the scheme are summarised in Table 13-15 and detailed in ES Appendix 13.9 Non-significant effects (Document Reference 6.4). Considering the location and extent of the calculated zone of groundwater drawdown it is unlikely that unknown groundwater abstraction points would be impacted.

**Table 13-15 Summary of impacts to groundwater receptors during construction**

| Receptor | Value of receptor | Potential impact | Design/ Embedded mitigation | Magnitude of impact | Significance of effect |
|---|---|---|---|---|---|
| **Impact on groundwater flow and levels** | | | | | |
| Cheltenham Sand and Gravel – Secondary A aquifer | Medium | Construction of widening the Existing A417 causing minor drawdown within the sands and gravel aquifer that overlies the Lias Group. No groundwater dependent features have been identified. | None | Negligible | Slight adverse |
| Lias Group – Secondary (undifferentiated) aquifer | Medium | | None | No impact | Neutral |

| Receptor | Value of receptor | Potential impact | Design/ Embedded mitigation | Magnitude of impact | Significance of effect |
|---|---|---|---|---|---|
| Tributary of Norman's Brook springs | High | Drainage (part of slope stabilisation at Crickley Hill) causing drawdown in cohesive superficial deposits. If these drains intersect permeable deposits, they have the potential to intercept groundwater flow that contributes to springs. | Drainage design to maintain water balance within specific sub-catchment | Negligible | Slight adverse |
| Inferior Oolite – Principal aquifer | High | Construction of cutting between Ch. 1+700 and 3+000 is likely to have an impact on groundwater flow paths, particularly near the Crickley Hill escarpment where it may intercept fissures and gulls that transport groundwater to groundwater dependent features at Crickley Hill | Development of voids protocol to maintain flow paths where possible | Negligible | Slight adverse |
| Tributary of Norman's Brook springs | High | The sprigs are outside radius of influence boundary of cutting Ch. 1+700 to 3+000, however there may be reduction in peak winter flow if cutting intersects karst in drainage invert within Inferior Oolite limestone aquifer. | Development of voids protocol to maintain flow paths where possible | Negligible | Slight adverse |
| Inferior Oolite – Principal aquifer | High | Dewatering and permanent drainage at B4070 link road cutting likely to intersect peak winter groundwater levels in the Great Oolite Group and may reduce groundwater flows towards seasonal emergence of groundwater in valley floor. Cutting level is above the maximum anticipated groundwater level in Inferior Oolite aquifer. | None | No change | Neutral |
| Dry valley at Shab Hill (headwaters of the tributary of River Churn) | Medium | | Drainage design to maintain water balance within specific sub-catchment | Negligible | Slight adverse |
| Great Oolite limestone – Principal aquifer | High | Excavation and dewatering of cuttings between Ch. 3+200 and 5+000 will result in removal of Great Oolite aquifer within the Severn Vale catchment which will cause a reduction in the | Drainage design to maintain water balance within specific sub-catchment | Negligible | Slight adverse |
| Alluvium – Secondary A aquifer | Medium | | | Negligible | Slight adverse |

| Receptor | Value of receptor | Potential impact | Design/ Embedded mitigation | Magnitude of impact | Significance of effect |
|---|---|---|---|---|---|
| Unnamed tributary of River Churn springs | Medium | resource extent and recharge area. | | Negligible | Slight adverse |
| Unnamed tributary of River Frome springs (east) | High | | | Negligible | Slight adverse |
| Bushley Muzzard SSSI<br>Unnamed tributary of River Frome springs (west) | High | No impact identified from groundwater dewatering and permanent drainage at cutting (Ch. 3+200 to Ch. 5+000) as located in separate sub-catchment. | None | No change | Neutral |
| Unnamed tributary of River Frome springs (east) | High | Dewatering from permanent drainage at cutting (Ch. 4+200 to Ch. 5+000) has potential to intercept winter peak groundwater levels | Drainage design to maintain water balance within specific sub-catchment | Negligible | Slight adverse |
| Baunton public water supply, SPZ3 | High | No impact identified from groundwater dewatering and permanent drainage at cutting (Ch. 4+200 to Ch. 5+000) as cuttings will be founded within the Great Oolite Group and hydraulically disconnected from the Inferior Oolite so potential impacts to flow are unlikely. | None | No change | Neutral |
| **Construction of embankments** | | | | | |
| Tributary of Norman's Brook springs | High | These springs are in the direct path of the scheme. They would be covered by embankment during construction with the tributary of Norman's Brook that they feed into. | Design of earth bund, embankments would include a drainage blanket and redirection of the springs to maintain water balance within the watercourse(s) | Negligible | Slight adverse |
| Dry valley at Shab Hill (headwaters of the tributary of River Churn) | Medium | | | Negligible | Slight adverse |
| **Impact on groundwater flows from foundations** | | | | | |
| Great Oolite limestone – Principal aquifer | High | Potential alteration of shallow groundwater flow pathways may occur | FWRA | Negligible | Slight adverse |

| Receptor | Value of receptor | Potential impact | Design/ Embedded mitigation | Magnitude of impact | Significance of effect |
|---|---|---|---|---|---|
| Inferior Oolite – Principal aquifer | High | around new overbridge foundations. Due to the minor extent of the foundations within the much larger area of aquifer impact is likely to be negligible.<br>Construction of piled foundations may impact groundwater flow and level in aquifers. However, the impact is likely to be very local. As the foundation's piles are likely to be constructed in groups with gaps in between individual piles, impact on groundwater flow is likely to be negligible. | | Negligible | Slight adverse |
| Unnamed tributary of River Churn springs | Medium | | | Negligible | Slight adverse |
| Unnamed tributary of River Frome springs (east) | High | | | Negligible | Slight adverse |

13.10.42 Given that a change in groundwater level or flow may impact upon identified groundwater-dependent features, mitigation is proposed in section 13.9 Design, mitigation and enhancement measures to reduce this impact to negligible. Therefore, the effect would be slight adverse and not significant.

13.10.43 Changes to groundwater flows and level would not impact waterlogged deposits that may preserve paleo-environmental material, as considered in ES Chapter 6 Cultural heritage (Document Reference 6.2).

*Groundwater quality*

13.10.44 Temporary works associated with the construction of cuttings, embankments and drainage basins have the potential to affect groundwater quality although this is likely to be localised and temporary.

13.10.45 Groundwater receptors have been identified by ground investigation, water level monitoring, groundwater quality sampling and testing, and geophysical surveys, to ensure that the location and connectivity with the scheme is understood prior to construction works. Available baseline hydrogeological conceptual model is presented in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4)). The groundwater receptors that may be affected by temporary works include Secondary aquifers contained in alluvium, Cheltenham Sand and Gravels and the Lias Group as well as the Principal aquifers in Inferior and Great Oolite limestones, and features dependent of these aquifers such as springs and seepages that form headwaters of the River Churn and River Frome. These are detailed in ES Appendix 13.9 Non-significant effects (Document Reference 6.4). The value of the receptors is presented in Table 13-13.

13.10.46 Temporary works associated with piled foundations associated with construction of Cotswolds Way crossing, Gloucester Way crossing, Cowley and Stockwell overbridges may also impact the groundwater quality. This is primarily of concern for the construction of the Cotswolds Way crossing, where fissures, gulls or karst may be encountered during construction within the Inferior Oolite limestones aquifer and pile grout has the potential to escape through these flow paths.

13.10.47 Following the implementation of mitigation set out in section 13.9 Design, mitigation and enhancement measures, the magnitude of any pollution incident or general impact on water quality is likely to be negligible. Therefore, the effect would be slight adverse and not significant.

GWDTEs

13.10.48 The assessment of effects on GWDTEs, particularly Bushley Muzzard SSSI, is presented in ES Appendix 13.8 GWDTEs Assessment (Document reference 6.4). It has been based upon the outputs from the hydrogeological impact assessments presented in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4).

13.10.49 This has evaluated the drawdown in groundwater levels associated with the scheme cuttings. The calculated drawdowns do not extend to the identified or potential GWDTEs, as shown on ES Figure 13.16 Groundwater impact assessment (Document Reference 6.3). Therefore, this would result in no change, with a neutral effect, which is not significant.

Flood risk

13.10.50 The risk of flooding to the DCO Boundary during construction of the scheme is considered to be low, although several areas at medium to high risk of pluvial flooding (around the tributary of Norman's Brook) and groundwater flooding have been identified in ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4) and are shown on ES Figure 13.21 Crickley Hill Surface Water Flooding – Scheme (Document Reference 6.3).

13.10.51 The risk of fluvial flooding to or from the scheme is low, however there are high areas of risk from surface water and groundwater flooding. Several ordinary watercourses cross the route of the scheme; however, these are too small to be represented on EA flood mapping. The watercourses typically have constricted valleys and existing topography means the flood risk they pose is low. There are no main rivers crossed by the scheme.

13.10.52 Surface water generated across the DCO Boundary would be managed by construction drainage (including suitably sized temporary settlement and drainage basins, drainage ditches and culverts). These would be installed early in the construction period as per ES Appendix 2.1 EMP (Document Reference 6.4), which would manage surface and groundwater flooding to ensure that flood risk does not increase as a result of the scheme.

13.10.53 Suitable practices, such as the storage of plant and materials outside of flood prone areas, are included within ES Appendix 2.1 EMP (Document Reference 6.4).

13.10.54 Following the implementation of mitigation outlined in ES Appendix 2.1 EMP (Document Reference 6.4), the risk posed by flooding to and from the DCO Boundary from construction is considered to be no change. Therefore, the effect would be neutral and not significant.

**Operational effects**

Surface water

*Surface water quantity*

13.10.55 The effects upon surface water quantity are principally related to new embankments, earth bund and cuttings and the interactions with existing water features. These potential effects are very similar during construction and operation of the scheme and have been discussed in full in the Construction Effects section (paragraph 13.10.8 onwards). The significance of effects is therefore considered to be the same as the construction assessment, with the exception of the tributary of Norman's Brook.

13.10.56 Following detailed design, the tributary of Norman's Brook would be within a new realigned channel. The design of the realigned channel is anticipated to have similar characteristics to the existing channel. With the sensitivity of the receptor being high, and magnitude of impact of negligible, the effect would be slight adverse and not significant.

*Surface water quality*

13.10.57 The drainage design of the scheme directs runoff from the mainline carriageway and realigned side roads to 12 outfalls to surface waters.

13.10.58 HEWRAT adopts a tiered approach as follows:

- Step 1: Runoff quality. This predicts concentrations of pollutants in untreated and undiluted highway runoff prior to any treatment and dilution in a water body.
- Step 2: In-river impacts. This predicts concentrations of pollutants after mixing within the receiving water body. At this stage, the ability of the receiving watercourse to disperse sediments is considered and, if sediment is predicted to accumulate, the potential extent of sediment coverage (i.e. the deposition index, DI) is also considered. Step 2 also incorporates two 'tiers' of assessment for sediment accumulation, based on different levels of input parameters. If one or more risks are defined as unacceptable at Tier 1, i.e. 'fail', then a more detailed Tier 2 assessment is undertaken, requiring values for further parameters relating to the physical dimensions of the receiving watercourse.
- Step 3: In-river impacts with mitigation. Steps 1 and 2 assume that the road drainage system incorporates no mitigation measures to reduce the risk. Step 3 includes mitigation in the form of Sustainable Drainage Systems (SuDS), considering the risk reduction associated with any existing measures or any proposed new measures.

13.10.59 A cumulative assessment has been undertaken for outfalls within 0.6 miles (1 kilometre) of each other for soluble pollutants and within 100m for sediment. Outfalls only qualified if they were within the same catchment. With embedded mitigation incorporated, all outfalls pass for sediment. All outfalls failed for soluble pollutants. Mitigation is therefore required within the detailed drainage design to ensure that the appropriate treatment levels are met. Details on the assessment are provided in ES Appendix 13.4 Water Quality Assessment (Document Reference 6.4).

13.10.60 It is therefore considered that the magnitude of impact of sediment and dissolved metals discharging into surface watercourse receptors is negligible. The effect would be slight adverse and not significant.

13.10.61 Effects upon designated areas (e.g. Bushley Muzzard SSSI) downstream of the discharge locations for the proposed drainage network are not anticipated.

*Hydromorphology*

13.10.62 Four new culverts are proposed within the scheme to enable the proposed highway to cross existing watercourses:

- Chainage 0+530 - Crickley Hill stream culvert (replacement of existing culvert).
- Chainage 1+450 - Grove Farm culvert.
- Chainage 3+200 - Shab Hill culvert.
- Chainage 4+775 - Stockwell culvert.

13.10.63 In addition to these culverts, there will be numerous smaller culverts conveying flows from the cut-off ditches under tracks and private accesses.

*Tributary of Norman's Brook*

13.10.64 Potential impacts on the hydromorphology of the tributary of Norman's Brook as a result of the replacement of the existing Crickley Hill stream culvert and the new Grove Farm culvert include local shading of the watercourses, local conversion of natural channel to culvert, scour at inlet and/or outlet if poorly designed and the structure acting as a barrier to sediment transport.

13.10.65 Provided the embedded mitigation, CD 529 Design of outfall and culvert details standard and CIRIA C786 Culvert, Screen and Operation Manual guidance is incorporated in the detailed design of the scheme, resulting minimal loss of natural watercourse length within culverts, but sediment transport and flow regimes maintained of the tributary of Norman's Brook by the replacement Crickley Hill stream culvert and the Grove Farm culvert, the magnitude of impact is considered to be negligible.

13.10.66 With the sensitivity of the receptor being high, and magnitude of impacts of negligible, the effect would be slight adverse and not significant.

*Unnamed tributaries of River Churn*

13.10.67 Potential impacts on the hydromorphology of the unnamed tributaries of the River Churn as a result of the Shab Hill culvert and Stockwell culvert include scour at inlet and/or outlet if poorly designed and the structure acting as a barrier to sediment transport.

13.10.68 Provided the embedded mitigation, CD 529 Design of outfall and culvert details standard and CIRIA C786 Culvert, Screen and Operation Manual guidance is incorporated in the detailed design of the scheme, resulting in flow regimes being maintained for the unnamed tributaries of River Churn by Shab Hill culvert and Stockwell culvert, the magnitude of impact is considered to be negligible.

13.10.69 With the sensitivity of the receptor being medium, and magnitude of impacts of negligible, the effect would be slight adverse and not significant.

*Unnamed tributary of River Frome*

13.10.70 Potential impacts on the hydromorphology of the unnamed tributary of the River Frome as a result of new smaller culverts conveying flows from the cut-off ditches under tracks and private accesses include scour at inlet and/or outlet if poorly designed and the structure acting as a barrier to sediment transport.

13.10.71 Provided the embedded mitigation, CD 529 Design of outfall and culvert details standard and CIRIA C786 Culvert, Screen and Operation Manual guidance is incorporated in the detailed design of the scheme, which will allow sediment transport and flow regimes to be maintained, the magnitude of impact is considered to be negligible.

13.10.72 With the sensitivity of the receptor being high, and magnitude of impacts of negligible, the effect would be slight adverse and not significant.

*Unnamed tributary of Horsbere Brook*

13.10.73 Potential impacts on the hydromorphology of the unnamed tributary of Horsbere Brook as a result of new smaller culverts conveying flows from the cut-off ditches under tracks and private accesses include scour at inlet and/or outlet if poorly designed and the structure acting as a barrier to sediment transport.

13.10.74 Provided the embedded mitigation, CD 529 Design of outfall and culvert details standard and CIRIA C786 Culvert, Screen and Operation Manual guidance is incorporated in the detailed design of the scheme, which will allow sediment transport and flow regimes to be maintained, the magnitude of impact is considered to be negligible.

13.10.75 With the sensitivity of the receptor being medium, and magnitude of impacts of negligible, the effect would be slight adverse and not significant.

<u>Groundwater</u>

*Groundwater levels and flows*

13.10.76 The effects upon groundwater quantity would be principally related to new structures (with associated foundations) and the road drainage in cuttings, which may impact groundwater levels or flows. These potential effects are very similar during construction and operation of the scheme and are discussed in full in Construction Effects (paragraph 13.10.19 onwards).

13.10.77 Given that a change in groundwater level or flow may impact upon identified groundwater-dependent features, as detailed in Table 13-17, mitigation is proposed in section 13.9 Design, mitigation and enhancement measures to reduce this impact to negligible resulting in an overall slight adverse effect and not significant.

*Groundwater quality*

13.10.78 An assessment following Appendix C of LA 113 has considered the impact of infiltration of road runoff to groundwater for all discharge locations for the scheme and is presented in ES Appendix 13.4 Water quality assessment (Document Reference 6.4).

13.10.79 The assessment indicated a medium risk of impact which, in accordance with Appendix C of LA 113, requires a detailed assessment. This detailed assessment will be undertaken as part of the detailed design, on confirmation of the drainage solution. This assessment will be completed in accordance with methodology set out in paragraph 13.4.24.

13.10.80 Should the detailed assessment indicate that additional mitigation measures are required to reduce the risk to a suitable level, these may include the drainage design to incorporate feasible treatment, or where this is not possible, no infiltration would be permitted. Considering the high value of the receptor (groundwater supply and quality) and impact resulting in no change, the effect would be neutral and not significant.

*GWDTEs*

13.10.81 The assessment of effects on GWDTEs, particularly Bushley Muzzard SSSI, is presented in ES Appendix 13.8 GWDTEs Assessment (Document Reference 6.4). It has been based upon the outputs from the hydrogeological impact assessments presented in ES Appendix 13.7 Hydrogeological impact assessment (Document Reference 6.4).

13.10.82 This assessment has evaluated the drawdown in groundwater levels associated with the road drainage in cuttings. The calculated drawdowns do not extend to the identified or potential GWDTEs, as shown on ES Figure 13.16 Groundwater impact assessment (Document Reference 6.3). Therefore, the drawdowns would result in no change to the GWDTEs, with a neutral effect, which is not significant.

Accidental spillage

13.10.83 Assessment of accidental spillages of polluting substances from roads has been carried out using Appendix D as prescribed in LA 113 using vehicle numbers from 2039 AADT traffic flows, taken from the scheme's traffic model, to account for future growth (ES Appendix 13.6 Accidental spillage (Document Reference 6.4)).

13.10.84 On all roads, there is a risk that an accidental spillage or vehicle fire may lead to an acute pollution incident. LA 113 states that the pollution risk on any road is linked to the risk of a heavy goods vehicle road traffic accident. Where a spillage does reach a surface watercourse the pollution effect can be severe but is usually of short duration.

13.10.85 The acceptable risk of a pollution incident, as stated in LA 113, is an annual probability of less than 1%, or a return period of 1 in 100 years.

13.10.86 Using the assessment method prescribed in Appendix D of LA 113, the risk of spillages has been calculated for predicted future traffic conditions. The greatest risk of accidental spillage at any location is below 0.04% - well within the acceptable limit.

13.10.87 Based on the spillage assessment in ES Appendix 13.6 Accidental spillage (Document Reference 6.4), the magnitude of potential impact on surface or groundwater receptors is considered to be negligible. The effect would therefore be slight adverse and not significant.

Flood risk

13.10.88 The risk of flooding to the site during operation of the scheme is considered to be low, with very low risk of fluvial flooding. However, areas of medium to high risk of pluvial flooding, in particular around the tributary of Norman's Brook, and groundwater flooding have been identified in the ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4).

13.10.89 Outputs from preliminary modelling are presented in ES Appendix 13.3 Flood Risk Assessment (Document Reference 6.4). The modelling conducted has enabled an understanding of the existing surface water flood risk of the tributary of Norman's Brook.

13.10.90 Further detailed modelling will be undertaken during detailed design to fully understand the residual flood risk and to include the scheme following design of the realignment of the tributary of Norman's Brook and the scheme's drainage design, to ensure that flood risk does not increase as a result of the scheme. The detailed design of the tributary of Norman's Brook and the drainage system in this area, to control peaks to the inlet of the Norman's Brook culvert, will be undertaken to improve the resilience of the area. The scheme would be designed to not cause any detriment to fluvial, surface or groundwater flood risk.

13.10.91 It is anticipated that the greater standard of flood protection included for the scheme over the Existing A417 between Cowley junction and Witcombe would be a benefit to road users travelling through the area.

13.10.92 The magnitude of effect is therefore considered to be no change. Therefore, the effect would be neutral and not significant.

WFD compliance assessment

13.10.93 A WFD compliance assessment has been completed and is included in ES Appendix 13.2 WFD compliance assessment (Document Reference 6.2). This provides a description of the relevant water bodies with the study area and how they could be impacted by the scheme. This assessment is based on currently available WFD baseline data and design information for the scheme.

13.10.94 It is considered that the activities related to the scheme will not cause deterioration in the status of any WFD waterbodies or prevent them from achieving either 'Good Ecological Status' or 'Good Ecological Potential' by 2021 or 2027, following the mitigation described in Section 6 of ES Appendix 13.2 WFD compliance assessment (Document Reference 6.2) are implemented. The delivery of this mitigation is secured by its inclusion within ES Appendix 2.1 EMP (Document Reference 6.4).

13.10.95 ES Appendix 13.2 WFD Compliance assessment indicates that the scheme would not result in a change in status of any WFD quality elements or prevent any water bodies from reaching 'Good' status in the future. The magnitude of effect is therefore considered to be no change. Based on this it is considered the effect would be neutral and not significant.

## 13.11 Monitoring

13.11.1 DMRB LA 104 sets out the requirements of monitoring, as detailed in ES Chapter 4 Environmental assessment methodology (Document Reference 6.2).

**Construction**

13.11.2 Monitoring would be required pre and during construction phases of the scheme. The monitoring is set out in Annex G Ground and surface water management plan of ES Appendix 2.1 EMP (Document Reference 6.4).

13.11.3 Surface and spring water quality monitoring would be undertaken prior to and during construction to ensure that no detrimental effect of the water environment occurs, and to allow any pollution incidents to be identified and remedied. This would also build data on the effectiveness of design and mitigation measures within the drainage strategy to drive improvement in environmental performance for future projects. The water quality monitoring would consist of regular site visits to make visual and olfactory observations, the use of in-situ water quality monitoring and regular sampling for laboratory analysis. During site visits any evidence of unnatural sediment accumulation that may be attributed to the construction works would also be recorded and action taken if required.

13.11.4 Surface and spring water flow monitoring would be undertaken prior to and during construction to provide a holistic understanding of all aspects of the water environment in this locality, and the inter-relationships between groundwater, and surface water and particular elements of these including flow regime, water quality, ecology, and geomorphology.

13.11.5 The rationale of the monitoring scheme would identify groups of representative features to monitor, particularly watercourses, groundwater springs and groundwater boreholes.

13.11.6 The duration of this monitoring should be sufficient to provide baseline data to compare against subsequent monitoring during the construction of the scheme.

**Operation**

13.11.7 No significant operation effects are predicted. However, it is recommended that post construction a survey is undertaken of all new culverts to review the effectiveness of embedded mitigation and the function along the new diverted channel. If there is any evidence of excessive erosion or sedimentation further actions should be considered to remedy that impact in as sustainable a way as possible.

13.11.8 No likely significant adverse effects are identified for flood risk, therefore no monitoring is required.

## 13.12 Summary

13.12.1 The road drainage and water environment chapter describes the existing condition of the water environment in the study area before undertaking an assessment of the potential effects on the quality and quantity of surface and groundwaters, flood risk and WFD compliance as a result of the scheme.

13.12.2 Table 13-16 summarises the residual significant effects following the embedded mitigation through design and essential mitigation measures identified to address significant effects for the construction and operation of the scheme respectively.

13.12.3 The assessment of effects on the water environment from the construction of the scheme has found that following the incorporation of the mitigation measures included in the Annex G Ground and surface water management plan of Appendix 2.1 (Document Reference 6.4) there would be a moderate adverse effect on hydromorphology, due to the realignment of the tributary of Norman's Brook during the construction phase.

### Table 13-16 Summary of significant effects

| Receptor | Potential impact | Attribute | Quality | Value | Design and mitigation (essential) | Magnitude | Significance of effect |
|---|---|---|---|---|---|---|---|
| **Construction phase** | | | | | | | |
| Tributary of Norman's Brook | Realignment of existing watercourse | Hydromorphology | Potential for species protected under EU or UK legislation | High | None | Moderate | Moderate adverse |
| **Operational phase** | | | | | | | |
| None | | | | | | | |

# References

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