Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

Environmental Statement

Volume 2

Chapter 7: Water Environment

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Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

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7. Water Environment

7.1 Introduction

1) This chapter presents an assessment of the potential for likely significant effects of the Proposed Marl Hill Section on the water environment.

2) Water environment includes the sub-disciplines fluvial geomorphology, surface water quality and groundwater. Flood risk is covered separately in Chapter 8: Flood Risk. A Water Framework Directive (WFD) assessment can be found in Appendix 7.1. The scope of each sub-discipline is as follows:

- Fluvial geomorphology – the forms and functions associated with watercourses, and their interaction with the surrounding terrestrial environment including sediment transport, erosion and deposition
- Surface water quality – the quality of surface waters, and impacts arising from pollution
- Groundwater – the water contained within the pore spaces of rocks and soils, including quantity and quality and its availability as a water resource.

3) The report begins by reviewing the legislation and planning policies relevant to water environment. The assessment area and methodology for the assessment are then outlined. The nature and sensitivity of the existing baseline environment are then identified before an assessment is made of the potential effects on the water environment for the Proposed Marl Hill Section. Mitigation measures have been proposed to avoid, reduce or offset any potential effects and these embedded mitigation measures have been considered in the assessment, which are mentioned in Chapter 3: Design Evolution and Development Description. Additional mitigation measures are further outlined in Section 7.7.

4) This chapter is supported by the following technical appendices and figures:

- Appendix 7.1: Water Framework Directive Assessment
- Appendix 7.2: Groundwater Dependent Terrestrial Ecosystem (GWDTE) Assessment
- Appendix 7.3: Geomorphology Proforma
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7.2 Scoping and Consultations

7.2.1 Scoping

5) A water environment chapter was included within the Environmental Impact Assessment Scoping Report[1] which was submitted to the relevant planning authorities for comment in October 2019 followed by a Scoping Addendum in February 2021 due to design changes and refinements. Scoping Opinions were provided by each of the local authorities and these have been reviewed and October 2019 Scoping Report Responses incorporated into the assessment. Scoping comments and responses are outlined in Appendix 4.1. The Scoping Addendum did not result in any change to the assessment methodologies or criteria outlined in the Scoping Report.

6) The scope of assessment for water environment was defined in the Scoping Report[2]. Since production of the Scoping Report[3] some refinement to the elements scoped in / out has occurred following design changes and receipt of additional data. These have been outlined in Table 7.1 to inform the assessment presented in this chapter.

7) The Scoping Report included surface water hydrology as a specific sub-discipline and activities were identified that would have the potential to cause effects on the quantity and continuity of flow within surface water bodies. As these effects are assessed within one or more of the other sub-disciplines within this chapter or as part of Chapter 8: Flood Risk, the specific surface water hydrology sections are not included within this chapter. Instead, Table 7.1 identifies the matters and potential effects of relevance to surface water hydrology with the effects considered either within this chapter, or within Chapter 8: Flood Risk

[1] Jacobs (2019) Haweswater Aqueduct Resilience Programme Proposed Marl Hill Section - EIA Scoping Report.
[2] *Ibid.*
[3] *Ibid.*

Table 7.1: Summary of Matters Scoped In / Out of the Assessment Following Design Changes or Receipt of Additional Data since the Scoping Report[4]

Receptor	Matter / Potential Effect	Conclusion in the Scoping Report (October 2019) and Scoping Addendum (December 2020)	2021 Environmental Statement
Fluvial geomorphology (operation)	Changes to geomorphological processes and features as a consequence of permanent structures within the channel or crossings.	**Scoped in** for all watercourses being crossed / modified by permanent structures.	**Scoped out** – no new permanent structures required to accommodate overflow discharges.
Surface water hydrology (construction)	In-channel working and dewatering leading to changes to the typical flow regime locally and downstream.	**Scoped in** for all watercourses, as working technique and duration are currently unknown. An assessment on a case-by-case basis for each watercourse would need to be made to determine potential impacts.	This impact is assessed in Chapter 8: Flood Risk.
	Increase in runoff due to riparian vegetation clearance for road crossings and use of fords across watercourses.	**Scoped in** for all watercourses crossed by above-ground construction activities.	This impact is assessed in Chapter 8: Flood Risk.
	Restriction of flows (i.e. from culverts, bridges, crossings) leading to changes in flow depth and velocity under high flow.	**Scoped in** for all watercourses, as working technique and duration are currently unknown. An assessment on a case-by-case basis for each watercourse would need to be made to determine potential impacts.	This impact is assessed in Chapter 8: Flood Risk.
	Site compounds and materials storage – change in local runoff patterns and rates associated with compounds, storage areas, stockpiles and temporary drainage, leading to changes in stream flow.	**Scoped in** for all watercourses that could interact with the Proposed Marl Hill Section.	This impact is assessed in Chapter 8: Flood Risk.
Surface water hydrology (operation)	The existing aqueduct which would be abandoned would over time fill with groundwater. This water would be directed via the existing discharge	**Scoped in** – the extent of change at each location cannot be quantified at this time and would be assessed at the next stage.	This impact is assessed in Chapter 8: Flood Risk.

[4] Jacobs (2019) *op. cit.*

Receptor	Matter / Potential Effect	Conclusion in the Scoping Report (October 2019) and Scoping Addendum (December 2020)	2021 Environmental Statement
	pipes and would result in new constant discharges to surface waters.		
	Decommissioning works could lead to a change in local runoff and infiltration patterns and rates, leading to changes in stream flow.	**Scoped in –** this cannot be determined until the method of decommissioning is known.	This impact is assessed in Chapter 8: Flood Risk.
Surface water quality (construction)	WFD catchments that only interact with the proposed tunnel route, and not with proposed construction or enabling works.	Areas of tunnel construction (excluding excavation of tunnel shafts); likely to have a negligible effect on surface water quality.	**Scoped out –** watercourses encompassed by the proposed tunnel envelope.
	Increased pollution risk as a result of using polluting substances in the construction process, e.g. cement, oils, lubricants and tunnel slurry.	**Scoped in** for all watercourses.	**Scoped in –** for all watercourses that could interact with above-ground construction activities. A case-by-case basis for each watercourse has been made to determine potential impacts.
	There is a risk of accidental spillage of polluting substances or leakage from general equipment use and the movement of plant around the site.	**Scoped in** for all watercourses that could interact with above-ground construction activities.	A case-by-case basis for each watercourse has been made to determine potential impacts.
	Degradation of surface water dependent habitats.	Not referred to in scoping report.	**Scoped in –** surface water dependent habitats within the assessment area that interact with enabling / construction Proposed Marl Hill Section activities. **Scoped out –** surface water dependent habitats upgradient and / or outwith drainage catchments associated with above-ground enabling and construction activities.
Surface water quality (operation)	During operation groundwater ingress into the abandoned sections of the existing tunnel would occur. This water	**Scoped in –** an extensive Ground Investigation (GI) is programmed for Proposed Marl Hill Section, which would include water quality testing of the	**Scoped in –** however, assessed under decommissioning as potential ingress from the abandoned sections has been considered

Receptor	Matter / Potential Effect	Conclusion in the Scoping Report (October 2019) and Scoping Addendum (December 2020)	2021 Environmental Statement
	would most likely be discharged via pipes to surface watercourses and may impact upon surface water quality in receiving watercourses.	groundwater to identify any potential pollutants and the chemistry of the water (i.e. pH). Until this information is available the impact upon surface waters cannot be established and this would require further assessment.	separately in the assessment from the operation of the new asset.
Groundwater (construction)	Changes to groundwater recharge rates.	**Scoped out** for this assessment except where sensitive groundwater environment attributes are present, e.g. where the Proposed Marl Hill Section passes through a Groundwater Dependent Terrestrial Ecosystem (GWDTE).	Overall groundwater disruptions for GWDTEs are captured in Appendix 7.2.
	Changes to groundwater quality from leaks and spills.	**Scoped in** for areas overlying, or directly interacting with highly sensitive aquifers, and / or where sensitive groundwater environment attributes (such as abstractions or GWDTEs) are intercepted by the Proposed Marl Hill Section.	Enabling and construction phases.
	Changes to groundwater quality from use of cementitious materials.	**Scoped out** except where the Proposed Marl Hill Section interacts with sensitive fractured aquifers.	Limited use of wet concrete and cementitious grout during shaft construction and tunnelling which means this is now scoped out.
	Potential recharge of abstracted groundwater from dewatering could also cause the groundwater level to rise.	**Scoped in**.	No recharge to the ground for abstracted groundwater is proposed as part of the design. This aspect is therefore not assessed.
	Creation of vertical pathways between aquifers allowing contamination migration.	**Scoped in**.	There are no historical or existing contamination sources identified within the zone of influence of the vertical shafts. This aspect is therefore scoped out. Risks associated with accidental spillages are discussed separately.

Receptor	Matter / Potential Effect	Conclusion in the Scoping Report (October 2019) and Scoping Addendum (December 2020)	2021 Environmental Statement
Groundwater (operation)	Changes to groundwater flow direction or levels due to the below-ground aqueduct and other below-ground structures.	**Scoped out** except in the vicinity of GWDTEs or adjacent to shallow groundwater abstractions.	Overall groundwater disruptions for GWDTEs are captured in Appendix 7.2.
	Watertight new aqueduct may result in groundwater rebound.	**Scoped in**.	This is no longer a potential impact given that the decommissioning strategy would allow groundwater ingress to flow out of the redundant asset under gravity. There are no proposals to grout the existing tunnel section .
	The aqueduct is permanently filled with grout or cement.	**Scoped in**.	This is no longer a potential impact given that the decommissioning strategy would allow groundwater ingress to flow out of the redundant asset under gravity. There is no proposals to grout the existing tunnel section .

7.2.2 Consultation

8) During the course of this assessment, consultation has taken place with relevant statutory and non-statutory consultees, stakeholders and third parties, through both correspondence and face-to-face meetings. This has been summarised in Appendix 4.1.

7.3 Key Legislation and Guidance

9) Table 7.2 introduces relevant water environment legislation.

Table 7.2: Water Environment Key Legislation and Guidance

Applicable Legislation	Description
Water Environment (WFD) (England and Wales) Regulations 2017	Transposes the European Union (EU) WFD (2000/60/EC), into English and Welsh law. It establishes a legislative framework for the protection of surface waters (including rivers, lakes, transitional waters and coastal waters) and groundwaters.
Water Supply (Water Quality) Regulations 2016	Consolidates legislation concerning the quality of water supplies for human consumption in England. A further analytical parameter (radon) is added for the monitoring of water supplies intended for human consumption.
Water Act 2003	Parliamentary act amending the Water Resources Act 1991, Reservoirs Act 1975 and the Water Industry Act 1991. Makes provision in connection with land drainage and flood defence; contaminated land so far as it relates to the pollution of controlled waters; to confer on the Coal Authority functions in relation to the discharge of water from coal mines; to extend the functions of the Environment Agency in relation to the rivers Esk, Sark and Tweed and their tributaries so far as they are in England.
Water Resources Act 1991	Parliamentary act which legislates for the regulation of water resources, water quality, pollution and flood defence. Part II of the Act provides the general structure for the management of water resources.
Environmental Protection Act 1990	Parliamentary act which makes provisions for the improved control of pollution arising from certain industrial and other processes; to re-enact the provisions of the Control of Pollution Act 1974 relating to waste on land, with modifications in as regards to the functions of the regulatory and other authorities concerned in the collection and disposal of waste and to make further provision in relation to such waste.

10) National and local planning policies are covered in Chapter 5: Planning Policy and Context.

7.4 Assessment Methodology and Assessment Criteria

7.4.1 Assessment Methodology

11) Reference has been made to national and local policy documents, relevant British Standards, national guidance and other relevant information in determining the assessment methodology and criteria to be used.

12) The assessment is based on general Environmental Impact Assessment methodology and was undertaken in accordance with the following:

- The methodology described here sets out a list of criteria for evaluating the associated environment effects:
    - The importance (sensitivity) of the resource under consideration on a scale of sensitivity (i.e. very high, high, medium or low)

  - The magnitude of effect in relation to the resource that has been evaluated, quantified using the scale large, medium, small or negligible
  - The significance of effect using the scale major, moderate, minor and negligible. For significant effects (moderate and major), additional mitigation could be required to reduce the significance of the effect.
- An effect could be significant if it would meet at least one of the following criteria:
  - It could lead to an exceedance of defined guidelines or widely recognised levels of acceptable change (e.g. exceedance of an Environmental Quality Standard of a water quality parameter)
  - It is likely that the planning authority would reasonably consider applying a condition, requirement or legal agreement to the grant of consent to require specific additional mitigation to reduce or overcome the effect
  - It threatens or enhances the viability or integrity of an asset or resource group of interest
  - It is likely to be important to the ultimate decision about whether or not the planning application should be approved.
- To aid the determination of significance, the assessment of effects would take the following stepped approach:
  - Determine the relevant features, assets and resources
  - Derive their sensitivity (importance) based on the criteria set out in Table 7.3
  - Identify and consider the potential effects from each activity (considering embedded mitigation as detailed in Chapter 3: Design Evolution and Development Description and the Construction Code of Practice (CCoP) (Appendix 3.2))
  - Determine the magnitude of change likely as a result of the effects (Table 7.4)
  - Present the significant effects and then consider how additional mitigation could reduce negative effects.
- Consultation would be undertaken with the regulators and local authorities to support the assessment and development of mitigation
- A WFD assessment has been undertaken to support the Environmental Statement.

13) The groundwater assessment of potential effects described above has been based on an interpretation of data from desk-based sources. This characterised the groundwater environment intercepted by the Proposed Marl Hill Section and confirms groundwater levels (i.e. groundwater pressures above the tunnelled sections, areas of shallow groundwater conditions, geological settings and groundwater quality). Based on this information, a generic dewatering assessment has been carried out to determine an order of magnitude for temporary groundwater volumes expected to be extracted during shaft and tunnel construction through the geological and hydrogeological conditions present in the area. These dewatering assessments also consider the wider attributes and potential impacts on groundwater abstractions (licensed and unlicensed), GWDTEs and baseflow contributions to surface waters.

14) The assessment of GWDTEs has been primarily based on the methodology outlined in the UK Technical Advisory Group (UKTAG) guidance.[5] An initial high-level screening exercise has been undertaken, using Phase 1 habitat survey data for the Proposed Marl Hill Section, to identify those sites which could be groundwater dependent. A combination of standard National Vegetation Classification (NVC) surveys, high-level NVC surveys (which attribute an NVC classification to the site as a whole), and surveys that follow the Scotland & Northern Ireland Forum for Environmental Research (SNIFFER) WFD95 Wetland Typology methodology[6] has been focussed on those sites identified from the Phase 1 habitat surveys. The UKTAG guidance links the NVC classification (where available) to indicative ranges of groundwater dependency (i.e. high, moderate, low or non-groundwater dependent). Individual Conceptual Site

[5] UKTAG (2005) *Draft Protocol for Determining 'Significant Damage' to a 'Groundwater Dependent Terrestrial System*.
[6] SNIFFER (2009) *WFD95: A Functional Wetland Typology for Scotland – Project Report. Edinburgh*: SNIFFER.

Models (CSMs) have been developed for the refined list of potential GWDTEs. The CSMs bring together geological, hydrogeological and ecological information available for the site, supported by hydrogeological surveys, where possible, to conclude and confirm the presence of GWDTEs and attribute a degree of groundwater dependency. The prioritisation of GWDTEs has been derived by considering both the ecological designation of the site, and the degree of groundwater dependency of each GWDTE. The impact assessment has been determined using the CSM to project.

15) The methodology was agreed with relevant stakeholders as part of the Scoping Report[7] and subsequent engagement.

7.4.2 Assessment Criteria

16) The assessment criteria outlined in Table 7.3 to 7.5 have been used to determine whether likely environmental effects are considered significant or not. For the purposes of this Environmental Statement, anything with a moderate or above significance of effect is considered to be significant.

17) Sensitivity (Table 7.3) would reflect the importance of features outlined in key policy documents and legislation which can include, among other things, its level of designation, or protection. Table 7.4 provides the criteria used to assess the potential magnitude of effect. Table 7.5 provides an illustration of how the significance of effects are derived by combining the magnitude of effect and an asset / resources sensitivity to that change.

18) Where the matrix indicates two alternative options (e.g. slight / moderate), evidence would be provided which supports the reporting of a single significance category. This would consider the importance of receptor and duration and / or extent of works

[7] Jacobs (2019) *op. cit.*

Table 7.3: Water Environment Sensitivity Criteria

Sensitivity	Criteria	Fluvial Geomorphology	Surface Water Quality	Groundwater
Low	Attribute has a low quality and rarity on local scale	A highly modified watercourse that exhibits no morphological diversity and has a uniform channel, showing no evidence of active fluvial processes. Has likely been significantly affected by anthropogenic factors which could include modification of flow regime, resulting in a dry channel during prolonged dry periods. Morphological features and processes would be unlikely to be sensitive to temporary or permanent works.	Watercourse not having a WFD classification shown in a River Basin Management Plan (RBMP). Could have a large number of anthropogenic pressures and / or pollutant inputs from discharges and / or surrounding land use relative to flow volume, e.g. agricultural drainage channels / ditches. Habitats dependent upon fluvial or pluvial water sources not designated (i.e. wetlands).	Unproductive aquifers. Very poor groundwater quality and / or very low permeability make exploitation of groundwater unfeasible. No active groundwater supply. Industrial buildings that are currently not utilised, all derelict buildings and infrastructure that serve a single dwelling. Water feeding GWDTEs of low groundwater dependence with no designation or groundwater that supports a wetland not classified as a GWDTE, although may receive some minor contribution from groundwater.
Medium	Attribute has a medium quality and rarity on local scale	A watercourse showing signs of modification and exhibiting a limited range of morphological features (such as pools and riffles). The watercourse is one with a limited range of fluvial processes and is affected by modification or other anthropogenic influences. Morphological features and processes could be sensitive to change as a result of temporary or permanent works.	Watercourse not classified under WFD. May have a number of anthropogenic pressures and / or pollutant inputs from discharges and / or surrounding land use relative to flow volume. Supports limited non-licensed abstraction for non-potable supply. Supports water dependent Biodiversity Action Plan (BAP) habitats or local sites of importance for nature conservation.	Secondary B and Secondary Undifferentiated aquifers. Groundwater flow and yield and quality associated with small-scale private water abstractions (i.e. feeding fewer than 10 properties). Groundwater quality associated with SPZ3 (Source Catchment Protection Zone) associated with licensed abstractions and with licensed abstractions for which no Source Protection Zone (SPZ) is defined. Unoccupied residential and commercial properties and buildings. Water-feeding GWDTEs of low groundwater dependence with a national non-statutory UK BAP priority; or water feeding highly or moderately groundwater dependent GWDTE sites with no conservation designation.

Sensitivity	Criteria	Fluvial Geomorphology	Surface Water Quality	Groundwater
High	Attribute has a high quality and rarity on local scale	A watercourse that appears to be in natural equilibrium and exhibits a natural range of morphological features (such as pools and riffles). There is a diverse range of fluvial processes present, with limited signs of modification or other anthropogenic influences. Morphological features and processes would be sensitive to change as a result of temporary or permanent works.	WFD-classified watercourse achieving or having established RBMP objectives (for a later RBMP cycle) to achieve, Good physico-chemical and biological elements status (Good potential for Heavily Modified Water Bodies (HMWBs). Supports licensed small-scale substitutable abstraction for potable supply or extensive non-licensed private water abstractions (i.e. feeding 10 or more properties or supplying large farming / animal estates). Contains species protected under European Commission (EC) or UK legislation ecology and nature conservation but is not part of a protected site. Non-WFD-classified water bodies may be applicable if protected species are present, indicating good water quality and supporting habitat. Valuable water supply resource due to exploitation for public, private domestic and / or agricultural and / or industrial use, feeding fewer than 10 properties. Supports surface water dependent species protected under UK or EC legislation.	Secondary A aquifers. Groundwater flow and yield and quality associated with extensive non-licensed private water abstractions (i.e. feeding 10 or more properties or supplying large farming / animal estates). Groundwater quality associated with SPZ2 (Outer Protection Zone) associated with licensed abstractions. Residential and commercial properties and Grade II listed buildings. Water-feeding GWDTEs of low groundwater dependence with a high environmental importance and international or national value, such as Ramsar sites, Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Sites of Special Scientific Interest (SSSIs); or water feeding highly or moderately GWDTE with a national non-statutory UK BAP priority.

Sensitivity	Criteria	Fluvial Geomorphology	Surface Water Quality	Groundwater
Very High	Attribute has a high quality and rarity on regional or national scale	A watercourse that appears to be in complete natural equilibrium and exhibits a natural range of morphological features (such as pools and riffles). There is a diverse range of fluvial processes present with limited signs of modification or other anthropogenic influences. Morphological features and processes would be highly sensitive to change as a result of temporary or permanent works.	WFD-classified watercourse achieving High physico-chemical and biological elements status. Watercourse part of a site protected / designated under International / EC / EU or UK legislation (SAC, SPA, SSSI, Ramsar site). Non-WFD-classified watercourses may be applicable if part of a protected site. Supports major surface water abstraction for potable supply. Supports surface water dependent species protected by EC legislation.	Principal bedrock and superficial aquifers. Groundwater flow and yield associated with licensed groundwater abstractions. Groundwater quality associated with SPZ1 (Inner Protection Zone) associated with licensed abstractions. Buildings of regional or national importance, such as Grade I and II* listed buildings, scheduled monuments, hospitals, power stations and large industrial sites. Water-feeding GWDTEs with a high or moderate groundwater dependence with a high environmental importance and international or national value, such as Ramsar sites, SACs, SPAs and SSSIs.

Table 7.4: Water Environment Magnitude of Effect Criteria

Magnitude	Criteria	Fluvial Geomorphology	Surface Water Quality	Groundwater
Major	Results in loss of attribute and / or quality, and integrity of the attribute	Loss or extensive damage to habitat due to extensive modification of natural channel planform and / or sediment and flow processes. Replacement of a large extent of the natural bed and / or banks with artificial material.	Construction works near or adjacent to a watercourse likely to risk a major, measurable shift from baseline water quality during construction. Risk of adverse impacts on protected aquatic species. Construction works on multiple tributaries of a watercourse resulting in the risk of significant cumulative impacts on water quality during construction. Loss or extensive change to a designated nature conservation site or fishery. For WFD-classified water bodies, water quality impacts have the potential to cause deterioration in WFD status. Reduction in major potable abstraction. Long-term loss or change to water supply (quantity or quality).	Major or irreversible change to groundwater aquifer(s) flow, water level, quality or available yield which endangers the resources currently available. Groundwater resource use / abstraction is irreparably impacted upon, with a major or total loss of an existing supply or supplies. Changes to water table level or quality would result in a major or total change in, or loss of, a groundwater dependent area, where the value of a site would be severely affected. Changes to groundwater aquifer(s) flow, water level and quality would result in major changes to groundwater baseflow contributions to surface water and / or alterations in surface water quality, resulting in a major shift away from baseline conditions such as change to WFD status. Dewatering effects create significant differential settlement effects on existing infrastructure and buildings.
Moderate	Results in effect on integrity of attribute or loss of part of attribute	Moderate deterioration from baseline conditions, with partial loss or damage to habitat due to modifications and / or changes to natural fluvial forms, and processes. Replacement of the natural bed and / or banks with artificial material.	Construction works near or adjacent to a watercourse likely to risk a moderate, measurable shift away from baseline water quality during construction. Partial loss in productivity of a fishery. For WFD-classified water bodies, water quality impacts may contribute to, but not cause a reduction in watercourse WFD classification or its ability to achievement of WFD objectives.	Moderate long-term or temporary significant changes to groundwater aquifer(s) flow, water level, quality or available yield which results in moderate long-term or temporarily significant decrease in resource availability. Groundwater resource use / abstraction is impacted slightly, but existing supplies remain sustainable. Changes to water table level or groundwater quality would result in partial change in or loss of a groundwater dependent area, where the value of the site would be affected, but not to a major degree. Changes to groundwater aquifer(s) flow, water level and quality would result in moderate changes to groundwater

Magnitude	Criteria	Fluvial Geomorphology	Surface Water Quality	Groundwater
			Temporary disruption or deterioration in a water supply.	baseflow contributions to surface water and / or alterations in surface water quality, resulting in a moderate shift from baseline conditions upon which the WFD status rests. Dewatering effects create moderate differential settlement effects on existing infrastructure and buildings.
Minor	Results in some measurable changes in attribute's quality or vulnerability	Slight deterioration from baseline conditions, with partial loss / damage to habitat due to modifications and / or changes to natural fluvial forms and processes.	Construction works within the watercourse catchment that may result in a risk of a minor, measurable shift from baseline water quality during construction. Localised small-scale reduction in resource (potable water supply) availability.	Minor changes to groundwater aquifer(s) flow, water level, quality or available yield leading to a noticeable change, confined largely to the proposed programme of Works Changes to water table level, groundwater quality and yield result in little discernible change to existing resource use. Changes to water table level or groundwater quality would result in minor change to groundwater dependent areas, but where the value of the site would not be affected. Changes to groundwater aquifer(s) flow, water level and quality would result in minor changes to groundwater baseflow contributions to surface water and / or alterations in surface water quality, resulting in a minor shift from baseline conditions (equivalent to minor but measurable change within WFD status). Dewatering effects create minor differential settlement effects on existing infrastructure and buildings.
Negligible	Results in effect on attribute, but of insignificant magnitude to affect the use or integrity	Very slight change from surface water baseline conditions, approximating to a 'no change' situation.	No measurable change in water quality at any time during any phase of Proposed Marl Hill Section No impact on WFD measures and / or their ability to achieve WFD watercourse objectives. No change in resource (potable water supply) availability.	Very slight change from groundwater baseline conditions approximating to a 'no change' situation. Dewatering effects create no or no noticeable differential settlement effects on existing infrastructure and buildings.

Table 7.5: Significance of Effects

Importance/ Value of Feature		Magnitude of Impact			
		Negligible	Minor	Moderate	Major
	Low	Neutral	Neutral	Slight	Moderate / Large
	Medium	Neutral	Slight	Moderate	Large
	High	Neutral	Slight / Moderate	Moderate / Large	Large / Very large
	Very High	Neutral	Moderate / Large	Large / Very large	Very large

7.4.3 Embedded Mitigation and Good Practice

19) Embedded mitigation is inherent to the design, and good practice measures are standard industry methods and approaches used to manage commonly occurring environmental effects. The assessments presented in Section 7.6 of this chapter are made taking into account embedded mitigation and the implementation of good practice measures.

20) The need for any additional topic-specific essential mitigation identified as a result of the assessment in Section 7.6 is then set out separately in Section 7.7.

Embedded Mitigation

21) The design has sought to avoid impacts as part of the design process. Chapter 3: Design Evolution and Development Description explains the evolution of the design with input from the environmental team, including mitigation workshops and the use of GIS-based constraints data.

Good Practice Measures

22) Good practice measures are contained in Appendix 3.2: Construction Code of Practice (CCoP). Key measures include appropriate design of outfalls (as necessary), appropriate storage and management of potential pollutants, treatment of surface / construction water prior to discharge and establishment of non-working areas around watercourses and GWDTEs.

7.4.4 Assumptions and Limitations

23) General assumptions of the EIA process are outlined in Chapter 4: EIA Methodology and assumptions and limitations specific to water environment and of note have been summarised below:

- No groundwater quality dataset in relation to discharges from the existing aqueduct were available at the time of writing. A conservative approach has been taken with regards to the quality of groundwater that would discharge from the existing aqueduct, whereby we have assumed there would be an impact on the surface water quality downstream of the discharge location on the receiving watercourse. Further mitigation and controls relating to discharge of water from the decommissioning of the existing aqueduct are detailed in Section 7.7.3
- No Ground Investigation (GI) information was available at the time of writing. Assessments have been based on the nearest geological and hydrogeological information extrapolated from the wider available dataset
- The identification of potentially contaminated land relies on information discussed in Chapter 11: Soils, Geology and Land Quality
- Information relating to private water supplies (PWS) is based on data provided by United Utilities through consultation with landowners (initial consultation relating to proposed GI and PWS questionnaires). This information has not been verified by site surveys. The information provided at

the time of writing may have residual gaps and the presence of other non-identified PWS in the assessment area cannot be ruled out

- It has been assumed that no impact on surface / sub-surface receptors would be expected along the proposed tunnel route, including but not limited to surface waters and GWDTEs
- The identification of GWDTE sites is reliant on Phase 1 habitat survey data provided by United Utilities. In areas where no Phase 1 habitat survey data are available, potential GWDTE sites were unable to be identified. The extent of Phase 1 habitat surveys is described in Chapter 9: Ecology
- Geological and groundwater information specific to individual GWDTE sites is limited
- Hydrogeological surveys were not undertaken at all potential GWDTE sites; however, where not available the assessment was carried out with other sources of information. The assessment is considered to be robust for the purpose of an EIA. Sources of information available for each individual GWDTE site are discussed in detail in Appendix 7.2
- The high-level nature of the Phase 1 habitat surveys means that small localised areas of potential GWDTEs situated within areas of non-groundwater dependent habitats may not have been identified
- Standard NVC data are limited to a small proportion of GWDTE sites. Where possible, this has been supplemented with a high-level NVC survey and the SNIFFER WFD95 Wetland Typology methodology. For a minority of GWDTE sites, Phase 1 habitat survey data are the only ecological information available. CSMs for such GWDTEs would place stronger reliance on information collected during hydrogeological surveys (where undertaken), and the conclusions would be more conservative to reflect residual level of uncertainty
- Habitats classified as broadleaved deciduous woodlands could have hydroecological conditions able to support wet woodland habitats classifying as GWDTEs in some specific settings. Unless areas of wet woodland habitat are highlighted through the high-level NVC and SNIFFER WFD95 Wetland Typology methodology, it is assumed that broadleaved deciduous woodlands can be excluded from the GWDTE assessment
- Potential GWDTEs located within the GWDTE assessment area but well outside calculated dewatering zones of influence and / or not immediately downgradient of proposed works would be assumed as unlikely to be impacted. These are listed in Appendix 7.2 but no CSM has been developed
- Rates of groundwater ingress into the decommissioned aqueduct are assumed to increase at a linear rate over time and have been forecast up to 2055. Future uncertainties have limited the ability to provide a realistic forecast beyond 2055
- United Utilities would monitor the volume and water quality of discharges from the decommissioned aqueduct to provide information on tunnel condition
- The design would continue to evolve. At the time of writing the following vertical design assumptions would apply:
  - Trenches would be 5 m deep and 5 m wide for single lines and 50 m wide for multi-line connections
  - No excavation would be required for the access roads and construction platforms and compound areas
  - 2 m deep excavations would be required for attentuation ponds
  - All topsoil strip areas would excavate 0.5 m below surface level maximum with no variance.

7.5 Baseline Conditions

24) This section details the water environment baseline for the assessment area and identifies assets where there is potential for significant effects to arise. Table 7.6 provides an overview of the assessment areas adopted for the water environment baseline and assessment. The assessment areas for Proposed Marl Hill Section for are shown on Figure 7.1.

Table 7.6: Water Environment assessment areas

Sub-discipline	Assessment Area	Description
Fluvial geomorphology	500 m	This allows for the consideration of impacts on surface water features outside the Proposed Marl Hill Section.
Surface water quality	500 m	Defined as an area around the above-ground activities related to Proposed Marl Hill Section (e.g. construction areas, site compounds, construction laydown areas and haul routes).
Groundwater	1 km	In all directions around the Proposed Marl Hill Section, except for GWDTEs.
	200 m	GWDTEs only: referred to as the overarching GWDTE assessment area. Covers an area in all directions around the Proposed Marl Hill Section (i.e. excluding tunnel sections carried out at depth). Within this wider assessment area, the zone of influence of dewatering for the nearest shaft has been used as a buffer around all surface works items (including access roads, open-cut connections, construction platforms, attenuation ponds) as a way of prioritising those sites which could experience significant direct or indirect effects as a result of the development, and which would require the creation of individual CSMs. This is referred to as the refined GWDTE assessment area.

7.5.1 Information Sources

25) Baseline data were collated from a variety of sources in compiling this assessment. These are outlined below.

Desk-based Study

26) The assessment was undertaken with reference to the sources detailed in Table 7.7.

Table 7.7: Key Information Sources

Data Source	Reference
Multi-Agency Geographic Information for the Countryside (MAGIC) – including information on aquifer designations, Environment Agency groundwater source protection zones (SPZs) and Ordnance Survey maps (1: 10,000, 1: 25,000, and 1: 50,000 scale)	https://magic.defra.gov.uk/MagicMap.aspx (Accessed July 2019 and January to April 2020)
Light Detection and Ranging (LiDAR) Digital Terrain Model	https://data.gov.uk/dataset/3fc40781-7980-42fc-83d9-0498785c600c/lidar-composite-dtm-2019-1m (Accessed January 2020)
The Environment Agency's Catchment Data Explorer	http://environment.data.gov.uk/catchment-planning/ (Accessed July 2019 and January to April 2020)
British Geological Survey (BGS) data	http://www.bgs.ac.uk/data/mapViewers/home.html (Accessed July 2019 and January to April 2020)
British Geological Survey (BGS) Susceptibility to Groundwater Flooding	Data supplied by Groundsure – https://www.groundsure.com/ (Accessed July 2019)
National Biodiversity Network Atlas (NBN)	https://nbnatlas.org/about-nbn-atlas/ Accessed January to July 2020

Data Source	Reference
Designated nature conservation sites citations	https://designatedsites.naturalengland.org.uk/ (Accessed January to July 2020)
Historical maps	http://maps.nls.uk/geo/explore/side-by-side/#, (Accessed July 2019)
Aerial imagery	http://www.magic.gov.uk/ (Accessed July 2019)
National soils mapping	http://www.landis.org.uk/soilscapes/ (Accessed January to July 2020)
United Utilities Surface Water Abstraction Dataset	Consultation
United Utilities cross-sections and historical information on depth of existing infrastructure	Consultation

Site Work

27) A fluvial geomorphology site walkover was undertaken between 14 and 16 January 2020 and on 22 April 2020. The site walkovers included all watercourses that potentially could be impacted by the Proposed Marl Hill Section. Fluvial geomorphological features and processes were identified and recorded using handheld mappers and photography. The extent of each survey was based on watercourse sensitivity determined during the desk-based assessment as follows:

- 1 km reach for very high and high sensitivity watercourses
- 250 m reach for medium sensitivity watercourses
- Single, spot check for low sensitivity watercourses.

28) The data from the site walkover were used to validate assumptions made during desk-based analysis, particularly the sensitivity of the watercourses, and identify geomorphological features and processes not readily identifiable from desk-based sources.

29) Hydrogeological site walkovers were undertaken at potential GWDTE sites within the overarching GWDTE assessment area, between 20 April and 19 May 2020. These surveys recorded the presence and characteristics of:

- Groundwater features: springs, seepages, flushes, upwelling
- Surface water features: including watercourses, areas of ponding, key overland flow routes, drainage ditches, land drainage pipes
- Soil and bedrock exposures and outcrops and general or localised observations on topography and land use.

30) Ecological site walkovers were also undertaken within the GWDTE assessment area (provided by United Utilities), and consisted of:

- Phase 1 habitat survey data
- Standard NVC data
- High-level NVC data, which attributed an NVC classification to the GWDTE site as a whole
- Data obtained using the SNIFFER WFD95 Wetland Typology methodology.

7.5.2 Baseline Overview

Fluvial Geomorphology

31) Appendix 7.3 contains a summary of the current fluvial geomorphology baseline of watercourses which could interact with the Proposed Marl Hill Section. Watercourse locations can be found on Figure 7.2.

32) In the Scoping Report[8] sensitivities were assigned to the watercourses which were known to interact with the Proposed Marl Hill Section, based on available information. Since the Scoping Report[9] was produced, the design of the Proposed Marl Hill Section has changed, with additional watercourse interactions identified. A summary of the scoped-in watercourses, the corresponding sensitivity and interaction with the Proposed marl Hill Section has been provided in Table 7.8.

33) For Bashall Brook the sensitivity has been changed from the Scoping Report from high to medium due to in-channel modifications noted on site.

34) There are four high and seven medium sensitivity watercourses carried forward for further assessment in the Proposed Marl Hill Section for fluvial geomorphology.

[8] Jacobs (2019) *op. cit.*
[9] *Ibid.*

Table 7.8: Fluvial Geomorphology Watercourses and Sensitivities

Sensitivity from Scoping Report	Revised Sensitivity for Environmental Statement	Watercourse Name	Description	Project Interaction
Not in Scoping Report	High	Bonstone Brook (W498)	A meandering channel with a range of geomorphological processes and features. Step pools, lateral and medial bars, and 150 m of bank erosion were all observed. Modifications noted within the study reach include bridges, culverts, a weir, Haweswater Aqueduct pipe bridge, a trash screen, and 20 m of bank reinforcement. The channel appeared to be in natural equilibrium but due to the modifications a high sensitivity has been assigned.	Within 500 m of construction access route and site compound (potential impact pathway). Dewatering during decommissioning of existing aqueduct.
Not in Scoping Report	High	Sandy Ford Brook (W530)	A sinuous channel with a range of geomorphological processes and features. Point, lateral, and medial bars, step pools, berms, and 60 m of bank erosion were all observed. Modifications noted within the study reach include bank reinforcement and a culvert. The channel appeared to be in natural equilibrium but due to the limited modifications a high sensitivity has been assigned.	Crossed by construction access route. Receiving discharge from site compound drainage and from commissioning flows. Within 500 m of site compound (potential impact pathway).
Not in Scoping Report	High	Unnamed Watercourse 426 (W516)	A sinuous tributary to Bashall Brook, evidence of bank failure along the left bank and gravel deposits suggests geomorphic processes, whilst the channel is likely to have a step-pool bedform sequence. Modifications consisted of one culvert. Due to limited modification this watercourse has a high sensitivity.	Dewatering during decommissioning of existing aqueduct.
Not in Scoping Report	High	Unnamed Watercourse 430 (W520)	A sinuous channel with step pools, berms, and 70 m of bank erosion observed within the study reach. Modifications were limited to a culvert. The range of geomorphological processes and features and limited modifications give this watercourse a high sensitivity.	Crossed by construction access route.

Sensitivity from Scoping Report	Revised Sensitivity for Environmental Statement	Watercourse Name	Description	Project Interaction
Not in Scoping Report	Medium	Unnamed Watercourse 402 (W483)	A sinuous channel with geomorphological processes and features limited to cobble steps. Modifications include an artificial embankment. As the modifications were limited this watercourse has a medium sensitivity.	Receiving discharge from site compound drainage and from commissioning flows.
Not in Scoping Report	Medium	Unnamed Watercourse 403 (W484)	A small sinuous tributary to Bonstone Brook that appears to be dry in its headwaters during summer months. There are likely to be a limited range of geomorphic features, including a step-pool bedform sequence. Therefore, a medium sensitivity has been assigned.	Dewatering during decommissioning of existing aqueduct.
Not in Scoping Report	Medium	Unnamed Watercourse 431 (W521)	A straight channel with geomorphological processes and features limited to cobble steps. Modifications include a culvert. As the modifications were limited this watercourse has a medium sensitivity.	Crossed by construction access route.
Not in Scoping Report	Medium	Cow Hey Brook (W535)	A low sinuosity channel exhibiting some geomorphological processes, cobble gravel steps with some localised adjacent grasslands. Erosion, deposition and bank failure process were evident. Modifications include a concrete channel along the upstream extent of the surveyed reach. Modifications are relatively extensive along the impacted reach, so this watercourse has a medium sensitivity.	Dewatering during decommissioning of existing aqueduct.
Not in Scoping Report	Medium	Unnamed Watercourse 433 (W523)	A gently sinuous channel with some geomorphological processes. Cobble steps and 10 m of bank erosion were observed. Modifications include a culvert. As the modifications were limited this watercourse has a medium sensitivity.	Crossed by construction access route.
High	Medium	Bashall Brook (W556)	A sinuous channel with a range of geomorphological processes and features. Point, lateral, and medial bars, cobble steps, berms and 60 m of bank erosion were all observed. Modifications noted within the study reach include bed and bank reinforcement, an earth embankment, a bridge and a weir. Although this watercourse exhibited a range of processes and	Receiving discharge from groundwater ingress (during decommissioning).

Sensitivity from Scoping Report	Revised Sensitivity for Environmental Statement	Watercourse Name	Description	Project Interaction
			features, due to the extensive modifications a medium sensitivity has been assigned.	
Not in Scoping Report	Medium	Unnamed Watercourse 463 (W557)	A straight channel with step pools and 20 m of bank erosion observed. Modifications noted within the study reach include a culvert. Although the geomorphological processes and features were limited, the modifications were also limited giving this watercourse a medium sensitivity.	Crossed by construction access route.

Surface Water Quality

35) Two surface water WFD water bodies and associated catchments have been identified that interact with the Proposed Marl Hill Section within the assessment area. The baseline WFD data and sites within the catchment that are protected / designated under EC or UK habitat legislation (SAC, SPA, SSSI, Water Protection Zone (WPZ), Ramsar site, salmonid water, water quality zones) are outlined in Table 7.9 and Figure 7.3. The WFD data provide an indication of water quality as the overall status comprises of physico-chemical quality elements and chemical water quality elements. For further details on each of the catchments to which the Proposed Marl Hill Section interacts refer to Appendix 7.4.

Table 7.9: Baseline WFD Data and Sites Within the Catchment

Element	Hodder – confluence (conf) Easington Bk to conf Ribble	Bashall Brook
Water body ID	GB112071065560	GB112071065520
Catchment size	69.3 km^2	17.8 km^2
Hydromorphological designation	Not designated artificial or heavily modified	Not designated artificial or heavily modified
Overall status	Moderate	Moderate
Ecological status	Good	Moderate
Physico-chemical quality elements	High	Moderate
Chemical status	Fail	Fail
Designated Sites within the catchment (SSSI / SAC / SPA / Area of Outstanding Natural Beauty (AONB)	Bowland Fells SSSI Bowland Fells SPA Forest of Bowland AONB	Forest of Bowland AONB
Atlantic salmon	Yes	Yes
Surface water abstractions	No	No
Surface water dependent habitats	Yes	No
High-priority surface water pesticide issue area	No	Yes
High-priority faecal indicator organisms issue area	Yes	Yes
High-priority phosphates issue area	Yes	No
Project interaction	Proposed access routes, site compounds, construction laydown areas and other above-ground activities associated with the Proposed Marl Hill Section (specifically the Bonstone Compound) are located within the River Hodder catchment.	Proposed access routes, site compounds, construction laydown areas and other above-ground activities associated with the Proposed Marl Hill Section (specifically the Braddup Compound) are located within the Bashall Brook catchment. Construction areas would not

Element	Hodder – confluence (conf) Easington Bk to conf Ribble	Bashall Brook
	However, construction activities would not lie within 500 m of the River Hodder.	lie within 500 m of Bashall Brook; however, the existing aqueduct outfall does.

36) Due to the large number of surface water features that interact with the Proposed Marl Hill Section and the limited information on non-WFD-classified water features, the baseline assessment has been conducted on a catchment-based approach. These have been briefly summarised below.

River Hodder (Conf of Easington Beck to Conf of River Ribble)

37) The Hodder – conf Easington Bk to conf Ribble, herein referred as the 'River Hodder', is an Environment Agency Main River[10] and holds an overall moderate classification under WFD. The watercourse has a WFD status of good for overall, ecological, biological quality elements and chemical parameters in addition to a high status for physico-chemical status.

38) Land use within the catchment is approximately 95 % rural, with isolated residential holdings, farmsteads, fields and areas of wooded plantations and mountainous regions interlinked by minor unnamed roads and the B6478 in the north-west of the catchment. No designated SSSIs, SPAs or SACs occur within 500 m of above-ground-related construction activities. The western-most point of the catchment encompasses part of Marl Hill Fells SSSI and SPA; the catchment is also encompassed by the Forest of Bowland AONB (refer to Appendix 7.4 for further details on these designations).

39) A number of surface water dependent habitats also occur within the assessment area associated with the Bonstone Compound; however, only one has been identified to interact with the above-ground activities. This habitat includes an area of Good Quality Semi-Improved Grassland (centred on National Grid Reference (NGR) SD7001448596). Additional information is provided in Appendix 7.4.

40) No surface water abstractions have been identified within the assessment area associated with the Bonstone Compound.

41) There are a number of watercourses which could potentially interact with the Proposed Marl Hill Section which are located within the River Hodder catchment. These unnamed watercourses are either tributaries of the River Hodder or are other water features, such as drainage channels or ditches. These are too small to be given a WFD classification. These watercourses, within the River Hodder catchment, are documented in Table 7.10 and shown on Figure 7.3.

Bashall Brook

42) Bashall Brook holds an overall moderate classification under WFD and a moderate status for ecological, physico-chemical and biological quality element parameters under WFD. Bashall Brook also holds specific objectives to achieve good status by 2027 including objectives for physico-chemical quality elements.

43) Land use within the catchment is approximately 90 % rural with isolated farmsteads and small residential holdings surrounded by cultivated fields and woodland areas interlinked by a minor road network. Southern parts of the catchment encompass part of the small village of Waddington. No designated SSSIs, SPAs or SACs occur within the catchment.

44) No surface water dependent habitats occur within the assessment area associated with the Braddup Compound and are therefore not discussed further.

45) One surface water abstraction has been identified within the assessment area associated with the Braddup Compound (Appendix 7.4). It has been identified that the abstraction occurs upstream of works and is therefore not discussed further.

[10] Defined as "usually larger rivers and streams designated as such and shown on the Main River Map"

46) There are a number of watercourses which could potentially interact with the Proposed Marl Hill Section which are located within the Bashall Brook catchment. These unnamed watercourses are either tributaries of Bashall Brook or are other water features, such as drainage channels or ditches. These are too small to be given a WFD classification. These watercourses, within the Bashall Brook catchment, are documented in Table 7.10 and shown on Figure 7.3.

Table 7.10: Surface Water Features Identified to Interact with the Proposed Marl Hill Section

WFD Catchment	Unnamed Water Feature ID	Project Interaction
River Hodder	1) Unnamed Watercourse 388 (W466) 2) Unnamed Watercourse 402 (W483) 3) Foulscales Brook (W465)	Within 500 m of Bonstone Compound and access route.
Bashall Brook	4) Unnamed Watercourse 430 (W520) 5) Unnamed Watercourse 431 (W521) 6) Unnamed Watercourse 433 (W523) 7) Sandy Ford Brook (W530) 8) Cow Hey Brook (W535) 9) Unnamed Watercourse 444 (W536) 10) Bashall Brook (W556) 11) Unnamed Watercourse 463 (W557)	Within 500 m of Braddup Compound and / or haul route and located within the drainage catchment of above-ground activities. Bashall Brook (W556) is only considered during the decommissioning phase of the impact assessment.

Groundwater

47) The proposed aqueduct along the Proposed Marl Hill Section is located fully below ground, up to a maximum of 130 meters below ground level (mbgl).

48) Table 7.11 and Table 7.12 provide descriptions of the lithology of each geological unit present, the aquifer designations for these deposits, and descriptions of the likely hydrogeological characteristics of the strata. Each bedrock formation may comprise several individual members and beds, but for this stage of the assessment the bedrock stratigraphic units have been discussed at the formation level only.

Table 7.11: Bedrock Aquifer Designation

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
Pendleside Limestone Formation	Fine to coarse grained, bioclastic commonly graded, cherty packstones, interbedded with wackestone, sporadic limestone conglomerate, and mudstone in the lower part.	Secondary A	Greatest yields are supported by fracture flow along bedding planes, solution enlarged fractures, and joints. The matrix of the limestones has a very low porosity and permeability, making negligible contribution to total groundwater flow. There is potential for karstification in places, and thus larger conduits. The unit has been proven to operate in discrete blocks due to extensive faulting. This forms an important local aquifer (multi-	Crossed by the Proposed Marl Hill Section.

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
			layered), providing water for potable and industrial use. Where boreholes have been tested in this formation, yields range from 240 m^3/day to 1920 m^3/day.	
Hodderense Limestone Formation	Wackestones, with micritic nodules, sporadic interbedded packstones and common mudstones.	Secondary A	Similar hydrogeological characteristics to the Pendleside Limestone Formation.	Crossed by the Proposed Marl Hill Section.
Hodder Mudstone Formation	Mudstone, with subordinate detrital limestone, siltstone and sandstone. Mudmound reef limestones, limestone boulder conglomerates and breccias near the base.	Secondary A	Argillaceous strata dominate, acting as aquitards or aquicludes, isolating the occasional sandstone horizons which act as separate aquifers. This is where most of the groundwater storage / movement occurs as both intergranular and fracture flow. Faulting has split the once continuous sandstone horizons into discrete blocks, to which no direct recharge can occur.	Crossed by the Proposed Marl Hill Section.
Clitheroe Limestone Formation	Packstones, wackestones and subordinate grainstones and mudstones with reef limestones.	Secondary A	Similar hydrogeological characteristics to the Pendleside Limestone Formation.	Lies within the wider groundwater assessment area.
Marl Hill Shale Formation	Mainly fissile and blocky mudstone, with subordinate sequences of interbedded limestone and sandstone.	Secondary A and Secondary Undifferentiated	Consists mainly of mudstone with low hydraulic conductivity which inhibits vertical hydraulic continuity. Predominantly an aquitard in this area.	Crossed by the Proposed Marl Hill Section.
Pendleton Formation	Pendle Grit Member Medium- to coarse-grained sandstone with subordinate interbedded	Secondary A	Moderately productive aquifer. Regionally significant multi-layered aquifer up to 900 m thick with yields of 5-10 litres per second (l/s),	Crossed by the Proposed Marl Hill Section.

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
	siltstone and mudstone.		rarely 50 l/s, with many springs.	

Table 7.12: Superficial aquifer Information

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
Till (diamicton)	Variable lithology, typically sandy, silty clay, with pebbles, but can contain gravel-rich, or laminated sand layers.	Secondary Undifferentiated	Typically mixed flow with varying permeability. Usually acts as an aquitard or aquiclude but can locally comprise productive sand and gravel horizons, which may yield limited amounts of groundwater, although groundwater abstraction is unlikely.	Crossed by the Proposed Marl Hill Section .
Peat	An accumulation of wet, dark brown, partially decomposed vegetation, or an organic rich clay.	Unproductive strata	Typically mixed flow with low permeability. Usually comprises 90 % water and acts as an aquitard, limiting groundwater discharge. Permeability varies with the degree of composition and soil compression and often reduces with depth.	Crossed by the Proposed Marl Hill Section.
Alluvium	Typically soft to firm, consolidated compressible silty clay, that can contain layers of silt, sand, peat, basal gravel, and a desiccated surface zone.	Secondary A	Typically intergranular flow with varying permeability. Where sand / gravel layers are thick and continuous, groundwater yields would be high, making local groundwater abstraction possible, although dominance of clay in this unit may limit its potential as an aquifer.	Lies within the wider groundwater assessment area.
Alluvial fan deposits	Alluvium, with a low-angle cone form.	Secondary A	Typically intergranular flow with high permeability. Similar hydrogeological characteristics to alluvium.	Crossed by the Proposed Marl Hill Section.
River terrace deposits	Sand and gravel, locally with lenses of silt, clay and peat.	Secondary A	Typically intergranular flow with high permeability. Sand and gravel deposits would typically comprise high porosity and high	Crossed by the Proposed Marl Hill Section.

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
			permeability and can locally yield significant groundwater volumes, if clay lenses are infrequent and sand / gravel deposits are of sufficient thickness. Local groundwater abstraction is unlikely.	

49) Table 7.11 and Table 7.12 described the location of the Proposed Marl Hill Section (including the proposed tunnel route indicative corridor), in relation to the bedrock formations and superficial deposits, i.e. whether they are directly crossed by the proposed route option, or whether they lie within the wider groundwater assessment area. The aquifer designation maps are shown on Figure 7.4 and Figure 7.5 for the bedrock and superficial deposits respectively.

50) Historical cross-sections for the existing aqueduct and limited historical nearby British Geological Survey boreholes records have been consulted. Due to the close proximity of the existing aqueduct to the Proposed Marl Hill Section it is anticipated that the encountered geology would be similar.

51) A long section produced using historical borehole data from the existing aqueduct suggested that, in the northern section of the tunnel, glacial till was encountered to a maximum proven depth of 5.5 m bgl. It is anticipated that the Bonstone Compound (reception) shaft would be constructed through the superficial glacial till and into a shaley mudstone of the Hodder Mudstone Formation. Following this, the cross-section suggested that mudstone and limestone of the Hodderense Limestone Formation, followed by interbedded mudstone, shaley mudstone and sandstone of the Marl Hill Shale with Pendleside Sandstone and Pendle Grit, would be encountered from north to south along the tunnel route.

52) The cross-section suggested that a fault, downthrown to the south, would be crossed where the tunnel passes into the Pendleside Sandstone Member, comprising sandstone, mudstone, shale and limestone. Following this, it is anticipated the tunnel would progress through more Marl Hill Shale, Pendleside and Hodderense Limestone and Hodder Mudstone. It is anticipated that the Braddup Compound (launch) shaft would be constructed through the superficial glacial till and into the Hodder Mudstone Formation. The historical borehole data from the existing aqueduct in the southern section of the tunnel indicated that glacial till can be expected up to a maximum proven depth of 10 m bgl.

53) It is understood that the historical boreholes were offset approximately 100 m in the north and approximately 300 m south-west from the existing aqueduct in the south from the Proposed Marl Hill Section. Historical BGS borehole (ref. SD74NW12), located approximately 100 m east of the Proposed Marl Hill Section, indicated a sand gravel / clay and clay gravel (till) to 1.5 m bgl, which was underlain by the Lower Marl Hill Shale Group. This comprised stiff clay, sandstone, broken limestone with voids to a maximum proven depth of 27 m bgl. Beneath the Marl Hill Shale the Pendleside Limestone Formation was proven to a maximum depth of 36 m bgl and comprised limestone.

54) Groundwater-level data were limited. The nearby historical BGS borehole (ref. SD74NW12), located within the tunnel section of the Proposed Marl Hill Section, recorded groundwater stood at 23.6 m, approximately 201 meters below ground level (mAOD), in the Lower Marl Hill Shale Group and Pendleside Limestone Formation.

55) No further groundwater data were available, but it was anticipated that groundwater levels were shallowest in watercourse valleys (where present) and shallow groundwater where present is likely to follow topography. Multiple springs were shown within the groundwater assessment area, which have been identified from BGS borehole mapping (see Figure 7.6).

56) No baseline groundwater chemistry data are available for the Proposed Marl Hill Section.

57) The eastern extent of the groundwater assessment area for the route overlaps with an SPZ2, relating to three groundwater abstraction licences associated with Waddington Fell Quarry, located approximately 1.5 km east of the tunnel route. Therefore, these groundwater licensed abstractions are outside of the groundwater assessment area.

58) Private Water Supply information is available based on information provided by landowners and third-party surveys,[11] six of which are present within the groundwater assessment area, as shown on Figure 7.6 and listed in Table 7.13. The supplies are used for domestic and agricultural purposes and it is understood that some sources supply several properties.

Table 7.13: PWS within the Groundwater Assessment Area

PWS Label	Approx. Distance from the Development Envelope of the Proposed Marl Hill Section (m)	Closest Feature	Type	Depth	Location and Comments
PWS4-1	Within the northern access road envelope	Northern access road	Spring	Unknown	Supplies more than one property in the Knowlmere estate but pipe network was only indicated to one of the properties. The estate extends around the northern end of the Proposed Marl Hill Section. Used for domestic and cattle irrigation purposes. Gravity-fed through underground pipes.
PWS4-2	Approx. 420 m to the east of the tunnel	Tunnel section T04	Spring	Unknown	Acts as the main supply to two properties to the south of spring location and as a standby to an additional two properties to the south of the spring location. It is understood that the source consists of a spring collection chamber which the groundwater is fed into by a plastic pipe. This then feeds two chambers located adjacent to Summit House Farm. One of the tanks acts as a pressure break tank. The supply to the first property is taken from these tanks into a separate tank within the attic of the property and gravity-fed. The pipe continues south where it feeds as a main supply to an additional property.
PWS4-3	Approx. 10 m to west of the tunnel)	Tunnel section T04	Borehole	Unknown	A borehole supply at Hodgson Moor Barn, which supplies the property on the land where it is located only.
PWS4-4	Approx. 1.25 km to the east of the tunnel	Tunnel section T04 / compound T04/B	Spring	Unknown	This supply is called Rushy Well and supplies the Colthurst Estate, which extends around the southern end of the Proposed Marl Hill Section. Water is used for domestic use and drinking water for cattle or irrigation purposes.

[11] Brassington, R (2020) *Investigation into the loss of supply from a spring at Summit House Farm, Waddington*.

PWS Label	Approx. Distance from the Development Envelope of the Proposed Marl Hill Section (m)	Closest Feature	Type	Depth	Location and Comments
					Water is pumped up to distribution tanks and distributed by gravity to the estate.
PWS4-5	Approx. 115 m to the east of the tunnel	Tunnel section T04	Borehole	36 m	A borehole supply, Moorfield Edge, which is understood to supply one property on the land where it is located.
PWS4-6	Within the Braddup Compound	Braddup Compound	Spring	Unknown	A spring supply, which is pumped from a tank via a pipe. Used for domestic and agriculture purposes. It is stated that the spring supplies '*all estate building*' and the nearby properties are all supplied from the same well. It was stated that the quality of the water had been tested by the council and was good. The exact location of the spring was not included in the questionnaire; however, the questionnaire refers to the estate map which is understood to be the Colthurst Estate. As this supply is described as a spring, it is assumed to be a separate source in addition to Rushy Well (PWS4-4).

Groundwater Dependent Terrestrial Ecosystems

59) Seven GWDTE sites have been identified within the refined GWDTE assessment area (see Figure 7.7). Five sites contain areas of low sensitivity and five sites contain areas of medium sensitivity. A summary of the sites in relation to the Proposed Marl Hill Section, their determined groundwater dependency classification, ecological designation and corresponding sensitivity is shown in Table 7.14.

60) A detailed assessment of the baseline conditions at each GWDTE site is provided in Appendix 7.2, along with a list of GWDTE sites identified within the overarching GWDTE assessment area.

Table 7.14: Summary of GWDTEs within the Refined GWDTE assessment area

Site Name	Approximate Shortest Distance from Proposed Marl Hill Section Planning Application Boundary (m)	Closest Feature	Assessment of Groundwater Dependency and Ecological Designation	Sensitivity
New Laithe	0	Bonstone Compound access track	High to low (with no designation)	Medium to low
Blue Gates	25	Bonstone Compound access track	Low (with no designation)	Low

Site Name	Approximate Shortest Distance from Proposed Marl Hill Section Planning Application Boundary (m)	Closest Feature	Assessment of Groundwater Dependency and Ecological Designation	Sensitivity
Braddup House	0	Braddup Compound, open-cut connection and overflow connection	Low (with no designation)	Low
Whinny Lane West	9	Braddup Compound, TR4/B shaft and attenuation pond	Moderate (with no designation)	Medium
Whinny Lane East	0	Braddup Compound access track	Moderate to low (with no designation)	Medium to low
Slaidburn Road West	0	Braddup Compound access track	Moderate to low (with no designation)	Medium to low
Thornbers	9	Braddup Compound access track	Moderate (with no designation)	Medium

7.5.3 Water Framework Directive

61) Fourteen WFD surface water bodies and one WFD groundwater body fall within the assessment area. Of these, 12 WFD surface water bodies have been scoped out based on distance from the Proposed Marl Hill Section components and likelihood of potential long-term effects.

62) Detailed information regarding the baseline conditions of each scoped-in WFD water body is provided in Appendix 7.1.

7.5.4 Summary of Sensitivity

63) The features and the assigned sensitivities for the water environment have been summarised in Table 7.15.

Table 7.15: Summary of Sensitivity

Feature Name	Sensitivity	Description
Fluvial Geomorphology		
Bonstone Brook (W498)	High	A meandering channel with a range of geomorphological processes and features. Some modifications.
Sandy Ford Brook (W530)	High	A sinuous channel with a range of geomorphological processes and features. Limited modifications.
Unnamed Watercourse 426 (W516)	High	A sinuous channel with a range of geomorphological processes and features. Limited modifications.
Unnamed Watercourse 430 (W520)	High	A sinuous channel with a range of geomorphological processes and features. Limited modifications.
Unnamed Watercourse 402 (W483)	Medium	A sinuous channel with limited geomorphological processes and features. Limited modifications.

Feature Name	Sensitivity	Description
Unnamed Watercourse 403 (W484)	Medium	A sinuous channel with a limited range of geomorphological processes and features. Likely to be ephemeral.
Unnamed Watercourse 431 (W521)	Medium	A straight channel with limited geomorphological processes and features. Limited modifications.
Unnamed Watercourse 433 (W523)	Medium	A straight channel with limited geomorphological processes and features. Limited modifications.
Bashall Brook (W556)	Medium	A sinuous channel with a range of geomorphological processes and features. Extensive modifications.
Unnamed Watercourse 463 (W557)	Medium	A straight channel with limited geomorphological processes and features. Limited modifications.
Surface Water Quality		
River Hodder (W477)	Very high	The River Hodder holds Good status for overall, ecological, biological quality elements chemical WFD parameters, as well as a High physico-chemical status. The watercourse has been assigned a very high sensitivity because of its physio-chemical status. No environmentally protected sites occur within the assessment area.
Unnamed Watercourse 388 (W466) Unnamed Watercourse 402 (W483) Foulscales Brook (W465)	Medium	Not classified under WFD. Hydrologically connected and / or a mainstem tributary of the River Hodder.
Surface water dependent habitat centred on SD7001448596 (good quality semi-improved grassland)	Medium	Contains BAP habitat.
Bashall Brook (W556)	High	Bashall Brook holds a Moderate classification status for overall conditions and physico-chemical parameters under WFD. However, the Bashall Brook also holds specific objectives to achieve Good status by 2027 including an objective for physico-chemical quality elements therefore justifying a High sensitivity.
Sandy Ford Brook (W530) Cow Hey Brook (W535) Unnamed Watercourse 463 (W557)	Medium	Not classified under WFD. Hydrologically connected, mainstem tributary, or part of a mainstem tributary of Bashall Brook.
Unnamed Watercourse 430 (W520) Unnamed Watercourse 431 (W521) Unnamed Watercourse 433 (W523)	Low	Not classified under WFD. Assessed to be artificial drainage channel.

Feature Name	Sensitivity	Description
Unnamed Watercourse 444 (W536)		
Groundwater		
Ashnott lead mine and lime kiln	Very high	Scheduled monument, located on a limestone knoll on the eastern valley side of Crag Beck and situated to the immediate east and south of Ashnott Farm, includes the earthworks and buried remains of Ashnott lead mine, together with the upstanding remains of a lime kiln.
SPZ2	High	Outer Protection Zone associated with the Inner Protection Zone where a well and a spring have been noted on maps near to Waddington Brook.
Pendleside Limestone Formation	High	Fine to coarse grained, bioclastic commonly graded, cherty packstones, interbedded with wackestone, sporadic limestone conglomerate, and mudstone in the lower part.
Hodderense Limestone Formation	High	Wackestones, with micritic nodules, sporadic interbedded packstones and common mudstones.
Hodder Mudstone Formation	High	Mudstone, with subordinate detrital limestone, siltstone and sandstone. Mudmound reef limestones, limestone boulder conglomerates and breccias near the base.
Clitheroe Limestone Formation	High	Packstones, wackestones and subordinate grainstones and mudstones with reef limestones.
Permian Rocks and Triassic Rocks (Undifferentiated)	High	Mainly fissile and blocky mudstone, with subordinate sequences of interbedded limestone and sandstone.
Alluvium	High	Typically soft to firm, consolidated compressible silty clay, which can contain layers of silt, sand, peat, basal gravel, and a desiccated surface zone.
Alluvial fan deposits	High	Alluvium, with a low-angle cone form.
River terrace deposits	High	Sand and gravel, locally with lenses of silt, clay and peat.
Various residential properties surrounding Proposed Marl Hill Section	High	Residential properties to the south of Cross Lane.
		Residential properties off Freeholds Lane.
		Residential properties to the north-west of Bonstone Compound.
		Residential properties off Browsholme Road.
Marl Hill Shale Formation	Medium	Mainly fissile and blocky mudstone, with subordinate sequences of interbedded limestone and sandstone.
Till (diamicton)	Medium	Variable lithology, typically sandy, silty clay, with pebbles, but can contain gravel-rich, or laminated sand layers.
PWS (all)	Medium	Six PWSfeeding less than 10 properties within the groundwater assessment area.
Peat	Low	An accumulation of wet, dark brown, partially decomposed vegetation, or an organic rich clay.

Feature Name	Sensitivity	Description
New Laithe	Medium to low	GWDTE with areas of high and low groundwater dependency (no ecological designation).
Blue Gates	Low	GWDTE with a low groundwater dependency (no ecological designation).
Braddup House	Low	GWDTE with a low groundwater dependency (no ecological designation).
Whinny Lane West	Medium	GWDTE with a moderate groundwater dependency (no ecological designation).
Whinny Lane East	Medium to low	GWDTE with areas of moderate and low groundwater dependency (no ecological designation).
Slaidburn Road West	Medium to low	GWDTE with areas of moderate and low groundwater dependency (no ecological designation).
Thornbers	Medium	GWDTE with a moderate groundwater dependency (no ecological designation).

7.6 Assessment of Likely Significant Effects

64) The following section describes the effects of the Proposed Marl Hill Section on the water environment during the enabling, construction, commissioning, operational and decommissioning phases.

7.6.1 Enabling Works Phase

65) The following provides an overview of the potential effects on the water environment as a result of the enabling works phase.

Fluvial Geomorphology

66) The enabling phase of the Proposed Marl Hill Section would include the following activities which could interact with the watercourses identified in the fluvial geomorphology baseline:

- Construction of site compounds (including earthworks, provision for compound drainage and sustainable drainage systems (SuDS), and creating areas of hardstanding) to provide a working area for construction phase activities
- Construction of temporary access routes (including earthworks and associated drainage)
- Earthworks associated with the upgrade of an existing access route
- Construction of culverts for temporary access routes.

67) Without any specific mitigation, these activities would have the potential to cause the following effects which are described in more detail below:

- Increased fine sediment input
- Changes to flow regime
- Loss of riparian vegetation
- Disturbance of channel bed and banks.

<u>Increased Fine Sediment Input</u>

68) Bonstone Brook would be within 200 m of Bonstone Compound and approximately 300 m from the access route to the compound. This watercourse exhibited several morphological features which could be affected by fine sediment (i.e. smothered) associated with the enabling works. However, due to the

distance from the Bonstone Compound, the effect would likely be minor, with a slight significance of effect.

69) Sandy Ford Brook would be approximately 20 m from Braddup Compound and would be crossed by its access route. This watercourse exhibited a range of geomorphological features and processes, specifically bars and step-pool features, which would be sensitive to changes in increases in supply of fine sediment. The impact would likely be moderate, and the significance of effect would be moderate.

70) Unnamed Watercourse 430 and Unnamed Watercourse 463 would be crossed by the access route to Braddup Compound. These watercourses exhibited a range of geomorphological features and processes which could be sensitive to disruption or loss as a result of an increased supply of fine sediment. The impact would likely be moderate; therefore, the significance of the effect would be moderate.

71) Unnamed Watercourse 431 and Unnamed Watercourse 433 would be crossed by the access route to Braddup Compound. The geomorphological features on both of these watercourses were limited to cobble steps, which would be sensitive to increased fine sediment input and siltation. Therefore, an increase in the supply of fine sediment during construction of the crossing during enabling works would likely have a minor impact on Unnamed Watercourse 431 and Unnamed Watercourse 433, with a slight significance of effect.

Changes to Flow Regime

72) Impacts associated with changes to flow regime are likely to be the same as those encountered during the construction phase of the Proposed Marl Hill Section and are discussed in greater detail in Section 7.6.2.

Loss of Riparian Vegetation

73) The upgrade to the access route to Braddup Compound would require the removal of riparian vegetation on Sandy Ford Brook, Unnamed Watercourse 430, Unnamed Watercourse 431 and Unnamed Watercourse 463. The riparian vegetation at the crossing locations included continuous trees. The watercourses were seen to be stable and removal of the vegetation is unlikely to have an impact on bank stability. Therefore, the impact would likely be negligible, with a neutral significance of effect.

74) The upgrade to the access route to Braddup Compound would require the removal of riparian vegetation on Unnamed Watercourse 433. The riparian vegetation at the crossing location included continuous trees. The channel was seen to be active, with some evidence of incision. Removal of vegetation could cause bank instability and lead to some further adjustment of the channel. Therefore, the effect of vegetation removal would likely be minor, with a slight significance of effect.

75) Clearance of riparian vegetation would be required for the construction of the outfall on Unnamed Watercourse 402. The riparian vegetation consisted of grasses, which is likely to have a minimal impact on bank stability. Therefore, the impact of vegetation removal would likely be negligible, and the significance of effect would likely be neutral.

Disturbance of Channel Bed and Banks

76) Culvert construction could cause compaction of bed substrate and disturbance of channel features on Sandy Ford Brook, Unnamed Watercourse 430 and Unnamed Watercourse 463. These watercourses exhibited a range of morphological features which could be lost or degraded by construction activity such as bars and step-pool features. Bank erosion was also observed which could be exacerbated by construction activity. Therefore, the impact would likely be moderate, with a moderate significance of effect.

77) Culvert construction could cause compaction of bed substrate and disturbance of channel features on Unnamed Watercourse 431 and Unnamed Watercourse 433. The geomorphological features on both of these watercourses were limited to cobble steps. Therefore, there would likely be a minor impact, with a slight significance of effect.

78) Outfall construction could disturb bed and bank features and cause compaction of bed substrate on Unnamed Watercourse 402. Geomorphological features were limited to cobble steps, which would likely be partially lost during construction of the outfall. This would likely have a minor impact on Unnamed Watercourse 402, with a slight significance of effect.

Surface Water Quality

79) During the enabling phase of the Proposed Marl Hill Section, the following activities have been identified as having the potential to impact on watercourses identified in the surface water quality baseline:

- Topsoil stripping during the construction of site compounds (earthworks, provision for compound drainage and SuDS, and creating areas of hardstanding)
- Construction of temporary access routes (including earthworks and associated drainage)
- Extension of existing culverts for temporary access routes
- Release of polluting substances (oils, fuels, chemicals and cement) from plant and machinery as well as storage
- The discharge of construction drainage to surface water features.

80) Without any specific mitigation (i.e. non-embedded mitigation), these activities for the enabling works would have the potential to cause the following effects on water quality which are described in more detail below:

- Sediment laden runoff
- Chemical pollution
- Bed and bank disturbance
- Impacts to surface water habitats.

<u>Sediment Laden Runoff</u>

81) Sediment laden runoff impacts which could lead to degradations in surface water quality would most likely be associated with activities of topsoil stripping, vegetation clearance, related earthworks required to construct the access tracks and formation of the site compounds and associated laydown areas.

82) Increased coverage of impermeable areas associated with the creation of the access roads and compounds increases the potential for larger runoff volumes to carry suspended solids to nearby water features.

83) For the Bonstone Compound and associated access route this would have the potential to impact tributaries of the River Hodder (Foulscales Brook, Unnamed Watercourse 388 and Unnamed Watercourse 402). Furthermore, site drainage would be discharged to Unnamed Watercourse W402 from the Bonstone Compound.

84) As a result, the magnitude of impact would be minor for Unnamed Watercourse 388 and Unnamed Watercourse 402 which have a medium sensitivity. This would result in a slight significance of effect for these watercourses. Due to the increased distance from the enabling activities and dilution effects the magnitude of impact for Foulscales Brook would be negligible for sediment laden runoff. This would result in a neutral significance of effect for this watercourse.

85) For the Braddup Compound and associated access route this would have the potential to impact tributaries of Bashall Brook: Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook, Cow Hey Brook, Unnamed Watercourse 444 and Unnamed Watercourse 463. Furthermore, site drainage would be discharged to Sandy Ford Brook from the Braddup Compound.

86) The magnitude of impact for all watercourses of medium and low sensitivity in relation to sediment laden runoff related to the Braddup Compound would be minor. This results in a slight significance of effect for Sandy Ford Brook, Cow Hey Brook and Unnamed Watercourse 463 and a neutral significance of effect

for Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433 and Unnamed Watercourse 444.

87) All scoped-in watercourses at the north of the Bonstone Compound flow into the River Hodder, through the Foulscales Brook. Due to the overall distance and dilution capacity of this watercourse and the River Hodder itself, the cumulative effect of sediment laden runoff would likely have a negligible magnitude of impact, with a neutral significance of effect on the River Hodder.

88) Similarly, all scoped-in watercourses associated with the Braddup Compound flow into Bashall Brook from these tributaries. Due to the overall distance from the site compound to Bashall Brook and the cumulative dilution capacity of the tributaries and Bashall Brook itself, the magnitude of impact of sediment laden runoff on Bashall Brook would be negligible. This would result in a neutral significance of effect on Bashall Brook.

Chemical Pollution

89) During the enabling phase, several potential pollutants would be present, including oils, fuels, chemicals, cement, waste and wastewater. Most of these potential pollutants would be stored within the compounds and associated laydown areas. In addition, there would be the potential for pollution to occur along the access tracks caused by spillages. This could impact on surface water quality should the pollutant reach the receiving watercourses.

90) The magnitude of any chemical pollution incident on surface water quality would depend on the volume of the spill / leak as well as conditions on site at the time, specifically related to how effectively the water environment would be able to buffer the incident. Where current and antecedent conditions on site have been wet and receiving watercourses have a high discharge volume, their dilution capacity would be high and the magnitude of incident would be reduced and, alternatively, lower discharges could increase the magnitude of relatively small volume spills.

91) The magnitude of impact would be minor for Unnamed Watercourse 388 and Unnamed Watercourse 402 which have a medium sensitivity. This would result in a slight significance of effect for these watercourses. A negligible magnitude of impact would be attributed to Foulscales Brook for chemical pollution. This would result in a neutral significance of effect for Foulscales Brook.

92) The magnitude of impact reported would be minor for all watercourses of medium and low sensitivity in relation to chemical pollution within the Bashall Brook catchment. This would result in a slight significance of effect for Sandy Ford Brook, Cow Hey Brook and Unnamed Watercourse 463 and a neutral significance of effect for Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433 and Unnamed Watercourse 444.

93) All scoped-in watercourses that are in the north of the Proposed Marl Hill Section flow into the River Hodder via the Foulscales Brook. Therefore, the cumulative effect of chemical pollution would likely have a negligible magnitude of impact, with a neutral significance of effect on the River Hodder.

94) Given the distance from the Braddup Compound to Bashall Brook and the associated dilution factors of both the Sandy Ford Brook and the Cow Hey Brook the magnitude of impact from chemical pollution on Bashall Brook would be negligible. This would result in a neutral significance of effect for Bashall Brook.

Bed and Bank Disturbance

95) Activities associated with the enabling phase of the Proposed Marl Hill Section require the need for working near to watercourses (i.e. within 50 m) to construct site infrastructure and potential for in-channel working to extend culverts. Near and in-water works have the potential to increase turbidity, affect pH and increase suspended solids leading to changes in surface water quality derived from disturbances to the bed and bank of the watercourses. Near or in-channel working would be required as part of the enabling works associated with the Braddup Compound on or near Unnamed Watercourse 402, Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook, Cow Hey Brook, Unnamed Watercourse 444 and Unnamed Watercourse 463. This work would include the extension of existing culverts associated with the site compound access route (due to be

upgraded) and to facilitate activities within the site compound. No culverts or culvert extensions would be required as part of the enabling works associated with the Bonstone Compound.

96) It is anticipated culvert extensions would be required along the length of the Braddup Compound access route to facilitate the proposed widening of the existing access. These potential culvert extensions would affect Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook and Unnamed Watercourse 463. Current site layout drawings indicate that a new culvert would be required on Cow Hey Brook to accommodate part of the site compound.

97) The impacts on surface water quality from bed and bank disturbance would not necessarily be confined to the immediate time period of their disturbance as, subject to reinstatement methods, impacts can continue to be realised during or after heavy rainfall.

98) Due to the requirement for the extension of culvert crossings on Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook, Unnamed Watercourse 463 and a new culvert crossing on Cow Hey Brook the magnitude of impact of bed and bank disturbance on surface water quality would be minor. This would result in a slight significance of effect for Sandy Ford Brook, Cow Hey Brook and Unnamed Watercourse 463, whereas the significance of effect for Unnamed Watercourse 430, Unnamed Watercourse 431 and Unnamed Watercourse 433 would be neutral.

99) For near channel works anticipated on Unnamed Watercourse 402 and Unnamed Watercourse 444 the magnitude of impact of bed and bank disturbance would be negligible. This would result in a neutral significance of effect for these watercourses.

100) Given the catchment connectivity of the listed watercourses, the cumulative impact on water quality arising from bed and bank disturbance on the River Hodder and Bashall Brook would be negligible. This would result in a neutral significance of effect for the River Hodder and Bashall Brook.

Impacts to Surface Water Habitats

101) One surface water dependent habitat has been identified within the assessment area associated with the Bonstone Compound. This identified habitat (NGR SD 70014 48596) consists of an area of Good Quality Semi-improved Grassland (indicating good water quality) which lies downgradient and within the drainage catchment of the proposed access track and therefore could be impacted by the activities outlined above (sediment laden runoff and chemical pollution).

102) The magnitude of impact on the area of Good Quality Semi-Improved grassland would be anticipated to be negligible resulting in a significance of effect of neutral.

Groundwater

103) The assessment of the potential effects of the enabling phase of the Proposed Marl Hill Section on groundwater covers two areas: groundwater flow and groundwater quality.

Groundwater Flow

104) During the enabling works phase, groundwater flow disturbance and / or dewatering impacts could occur as a result of various activities:

- Earthwork excavations for attenuation ponds
- Earthworks associated with site compound construction
- Earthworks associated with access roads.

105) During the enabling works phase, the only works that would involve excavation below 1 m of the ground surface would be the attenuation pond constructions at the Bonstone and Braddup compounds, which are expected to require 2 m-deep excavations.

106) There is uncertainty on groundwater levels due to the absence of any GI data and so a groundwater level of 1 m has been conservatively assumed at both the Bonstone and Braddup compounds. The dewatering of these excavations would therefore be expected to generate a localised impact on groundwater in the

superficial till (minor magnitude at the scale of the aquifer), resulting in a significance of effect of slight on superficial deposits.

107) All other works within the red-line boundary would be expected to have a negligible impact on groundwater flows within superficial deposits, resulting in potential neutral significance of effect.

108) The attenuation pond excavations are not expected to encounter the bedrock of the Hodder Mudstone at either of the compound locations; therefore, no dewatering effect would be expected on the bedrock at either of the locations and so no impact has been assessed.

109) All other works within the red-line boundary would be expected to have no impact on groundwater flows within the bedrock.

110) The Sichardt method (e.g. Preene *et al.*, 2016)[12] was used to estimate the dewatering radius of influence around each excavation at the Bonstone Compound and Braddup Compound that would be expected to intercept groundwater. This was applied using the estimated drawdown of groundwater levels to the base of the excavation. Due to the absence of any GI data, hydraulic conductivity values used in the calculation were obtained from generic values from the scientific literature (Domenico and Schwartz, 1990)[13] representative of the materials as per the published geology and materials encountered during the construction of the existing aqueduct.

111) However, where the estimated radius of influence is quite small, the method is considered to lack accuracy. Therefore, in order to ensure a suitable conservative assessment, a minimum radius of influence of 25 m has been assumed for both attenuation pond excavations in this case.

112) A review of impacts to potential receptors comprising PWS, GWDTEs, surface water, infrastructure and buildings, cultural heritage sites and contaminated land sites are presented in Appendix 7.5, conducted using the calculated zones of influence for each excavation area. The appendix also screens for other minor localised flow disruptions associated with activities within the red-line boundary including localised compaction which could impact on sensitive receptors such as PWS and GWDTEs. The review is based on the understanding of geology from published BGS maps and the geology encountered during the construction of the existing aqueduct, and a conservative estimate of the groundwater level across the Proposed Marl Hill Section.

113) As stated in Table 7.13 and shown in Appendix 7.5, the exact location of PW4-6, described as a spring of medium sensitivity, is unknown. A conservative assessment has been made that PWS4-6 could be directly impacted by the access track and the attenuation pond at the Braddup Compound during the enabling phase. This could result in a potential significance of effect of large.

114) As shown in Appendix 7.5, PWS4-1, described as a spring and of medium sensitivity, could be directly impacted (major magnitude) by the access track. This could result in a potential significance of effect of large.

115) Also, there is a large uncertainty on the network associated with PWS4-4 and PWS4-1 distributing respectively through the Colthurst and the Knowlmere estates. Part of the infrastructure could be directly impacted (major magnitude) which could result in a large potential significance of effect.

116) No impacts to licenced abstractions, cultural heritage sites, buildings or infrastructure including highways would be expected during this phase of works.

117) Significant potential impacts on groundwater flows supporting GWDTEs are summarised in Table 7.16. A detailed description of potential enabling phase impacts on groundwater levels and flows at all sites in the refined GWDTE assessment area is provided in Appendix 7.2.

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[12] Preene, M., Roberts, T.O.L. and Powrie, W. (2016) *Groundwater Control: Design and Practice*, second edition, CIRIA, C750. British Library Cataloguing in Publication Data. ISBN: 978-0-86017-755-5.

[13] Domenico, P.A. & Schwartz, F.W. (1990) *Physical and Chemical Hydrogeology*, John Wiley & Sons: New York.

Table 7.16: Summary of Potentially Significant Impacts on GWDTE Groundwater Flows

Site Name	Sensitivity	Activity/Effect	Magnitude of Impact	Significance of Effect
New Laithe	Medium to Low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Major	Large– Significant
Braddup House	Low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of compound (groundwater levels / flows).	Major	Large– Significant
Whinny Lane East	Medium to Low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Major	Large – Significant
Slaidburn Road West	Medium to Low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Major	Large– Significant

Groundwater Quality

118) Soil stripping and vegetation clearance would take place around site compound areas and associated access roads. Ground disturbance from this soil-stripping activity, as well as earthworks associated with access roads and SuDS construction, would potentially cause changes to groundwater quality due to mobilisation of soil and rock particles (suspended solids) which would migrate through the sub-soil and affect adjacent sensitive receptors (e.g. shallow groundwater abstractions and GWDTEs).

119) For works contained at the ground surface and shallow excavations less than 1 m deep, suspended solids would not migrate to any significant extent in intergranular aquifers due to the filtering effect of the unsaturated zone and aquifer material. In addition, the CCoP (Appendix 3.2) already refers to embedded mitigation measures associated with controlling silt pollution. Although, deeper excavations would create a more direct pathway to the aquifer and these effects may extend somewhat further.

120) As per Table 7.1, potential impacts on aquifers from silt contamination have been scoped out.

121) However, the assessment of effects from these activities on groundwater receptors such as groundwater-fed PWS and GWDTEs are provided in Table 7.17. Further details on impacts to groundwater quality at GWDTE sites is provided in Appendix 7.2. Groundwater abstraction sites potentially significantly impacted by the effects of the soil-stripping activity, as well as earthworks associated with access road and SuDS construction, would include PWS4-6.

Table 7.17: Potential Impact of Ground Disturbance on Key Hydrogeological Receptors

Groundwater Receptor	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
PWS4-6	Medium	Moderate	The exact location of PWS4-6 is unknown but could be present within the Braddup Compound or access road.	Moderate– Significant
No impact to other PWS or licensed abstractions would be expected.				
Whinny Lane East	Medium to Low	Moderate	Present within the Braddup Compound access area. Embedded mitigation would reduce the likelihood of pollution, but a high risk remains because of the sensitivity of the receptor and works taking place within the site.	Moderate– Significant

Groundwater Receptor	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
Slaidburn Road West	Medium to Low	Moderate	Present within the Braddup Compound access area. Embedded mitigation would reduce the likelihood of pollution, but a high risk remains because of the sensitivity of the receptor and works taking place within the site.	Moderate–Significant
All other GWDTEs are expected to receive effects with a slight or neutral significance of effect or receive no impacts.				

122) The CCoP (Appendix 3.2) also indicates that soil storage areas would be lined, ensuring that runoff is captured and there is no infiltration to the ground.

123) The CCoP (Appendix 3.2) already refers to guidance on pollution prevention measures which would be followed, along with setting up methodologies associated with fuel storage, and storage of materials and waste. This would include the development of a Construction Environmental Management Plan. These embedded mitigation measures would significantly reduce the risks to groundwater quality impairment and associated receptors resulting from accidental spillages.

124) The assessment of accidental spillages on aquifers and relevant receptors is provided in Table 7.18, considering the embedded CCoP (Appendix 3.2) measures.

Table 7.18: Potential Impact of Accidental Spillages on Key Hydrogeological Receptors

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of effect
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Minor	Present at the Bonstone Compound and access road, and Braddup Compound and access road	Slight
Secondary A superficial aquifer – river terrace deposits	High	Negligible	Present 140 m south-west of Bonstone Compound	Neutral
Secondary A bedrock aquifer – Hodder Mudstone Formation	High	Minor	Present at the Bonstone Compound and Braddup Compound	Slight
Secondary A bedrock aquifer - Pendletone Formation	High	Minor	Present at the south-west corner of the Braddup Compound	Slight
Secondary A bedrock aquifer – Clitheroe Limestone and Hodder Mudstone Formation	High	Minor	Present at the eastern half of the Braddup Compound and access road	Slight
PWS4-6, spring	Medium	Moderate	Exact location unknown but could be present within the Braddup Compound	Moderate–Significant

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of effect
Whinny Lane East	Medium to Low	Moderate	Present within the Braddup Compound access area. Embedded mitigation would reduce the likelihood of pollution, but a high risk remains because of the sensitivity of the receptor and works taking place within the site.	Moderate–Significant
Slaidburn Road West	Medium to Low	Moderate	Present within the Braddup Compound access area. Embedded mitigation would reduce the likelihood of pollution, but a high risk remains because of the sensitivity of the receptor and works taking place within the site.	Moderate–Significant
All other GWDTEs are expected to receive effects with a slight or neutral significance of effect or receive no impacts.				

125) Hard surfaces, including car parks, associated with office and welfare facilities at the compounds would be drained via small soakaway trenches local to the facilities. These would be small facilities with parking of small vehicles only and are not expected to represent a significant source of contamination. In accordance with the Environment Agency's approach to groundwater protection[14], the soakaway systems would meet government non-statutory technical standards for SuDS; would not discharge to a sensitive environment; and would not be located within 50 m of, or 250 m upgradient from, any abstractions intended for human consumption or food production purposes. The car park areas are expected to fall below the threshold requiring installation of an oil interceptor indicated in government guidance on pollution prevention for businesses[15] (less than 800 m^2 or 50 parking spaces).

126) In the absence of local GI information, it has been assumed that superficial deposits could be thin in the area of the compounds. Consequently, at the Bonstone Compound the potential magnitude of impact is considered to be minor on both bedrock and superficial aquifers, resulting in a significance of effect of slight on both the bedrock aquifer and superficial deposits. At the Braddup Compound the potential magnitude of impact is considered to be minor on both bedrock and superficial aquifers, resulting in a significance of effect of slight on both the bedrock aquifer and superficial deposits.

Summary of Effects

127) A summary of the enabling works phase effects is shown in Table 7.19.

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[14] The Environment Agency's Approach to groundwater protection - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf (February 2018 Version 1.2) [Online] [Accessed: 8 July 2020).

[15] Gov.uk Pollution prevention for businesses - https://www.gov.uk/guidance/pollution-prevention-for-businesses [Online] [Accessed: 8 July 2020).

Table 7.19: Summary of Enabling Works Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
Bonstone Brook (W498)	High	Increased fine sediment input	Temporary	Minor	Slight
Sandy Ford Brook (W530)	High	Increased fine sediment input	Temporary	Moderate	Moderate– Significant
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Moderate	Moderate– Significant
Unnamed Watercourse 430 (W520)	High	Increased fine sediment input	Temporary	Moderate	Moderate– Significant
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Moderate	Moderate– Significant
Unnamed Watercourse 402 (W483)	Medium	Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Minor	Slight
Unnamed Watercourse 431 (W521)	Medium	Increased fine sediment input	Temporary	Minor	Slight
		Changes to flow regime	Temporary	Negligible	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of impact	Significance of Effect (Pre-Mitigation)
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Minor	Slight
Unnamed Watercourse 433 (W523)	Medium	Increased fine sediment input	Temporary	Moderate	Moderate– Significant
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Minor	Slight
		Disturbance of channel bed and banks	Temporary	Moderate	Moderate– Significant
Unnamed Watercourse 463 (W557)	Medium	Increased fine sediment input	Temporary	Minor	Slight
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Minor	Slight
Surface Water Quality					
River Hodder (W477)	Very high	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
		Bed and bank disturbance	Temporary	Negligible	Neutral
Unnamed Watercourse 388 (W466)	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
Unnamed Watercourse 402 (W483)	Medium	Sediment laden runoff	Temporary	Minor	Slight

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of impact	Significance of Effect (Pre-Mitigation)
		Chemical pollution	Temporary	Minor	Slight
		Bed and bank disturbance	Temporary	Negligible	Neutral
Foulscales Brook (W465)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Bashall Brook (W556)	High	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
		Bed and bank disturbance	Temporary	Negligible	Neutral
Sandy Ford Brook (W530) Cow Hey Brook (W535) Unnamed Watercourse 463 (W557)	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
		Bed and bank disturbance	Temporary	Minor	Slight
Unnamed Watercourse 430 (W520) Unnamed Watercourse 431 (W521) Unnamed Watercourse 433 (W523) Unnamed Watercourse 444 (W536)	Low	Sediment laden runoff	Temporary	Minor	Neutral
		Chemical pollution	Temporary	Minor	Neutral
		Bed and bank disturbance	Temporary	Minor	Neutral
Good Quality Semi-Improved Grassland (SD7001448596)	Medium	Impact to surface water dependent habitat.	Temporary	Negligible	Neutral
Groundwater					
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Localised drawdown of the water table around attenuation ponds within superficial deposit layer.	Temporary	Minor	Slight
PWS4-6	Medium	Reduced flow capacity from ground compaction	Temporary	Moderate	Moderate– Significant

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of impact	Significance of Effect (Pre-Mitigation)
		Physical disruption of supply by construction activities.	Permanent	Major	Large– Significant
PWS4-4 and PWS4-1	Medium	Large uncertainty of pipe distribution network which could be directly impacted.	Permanent	Major	Large– Significant
New Laithe	Medium to low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Temporary	Major	Large– Significant
Braddup House	Low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Temporary	Major	Large– Significant
Whinny Lane East	Medium to low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Temporary	Major	Large– Significant
Slaidburn Road West	Medium to low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of	Temporary	Major	Large– Significant

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of impact	Significance of Effect (Pre-Mitigation)
		access tracks (groundwater levels / flows).			
PWS4-6	Medium	Changes to water quality due to ground disturbance from soil stripping and earthworks associated with access road.	Temporary	Moderate	Moderate– Significant
Whinny Lane East	Medium to low	Changes to water quality due to ground disturbance from soil stripping and earthworks associated with Braddup Compound access track.	Temporary	Moderate	Moderate– Significant
Slaidburn Road West	Medium to low	Changes to water quality due to ground disturbance from soil stripping and earthworks associated with Braddup Compound access track.	Temporary	Moderate	Moderate– Significant
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Changes to groundwater quality due to accidental spillages at Bonstone Compound and Braddup Compound.	Temporary	Minor	Slight
Secondary A superficial aquifer – river terrace deposits	High	Changes to groundwater quality due to accidental spillages at Bonstone Compound.	Temporary	Negligible	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of impact	Significance of Effect (Pre-Mitigation)
Secondary A bedrock aquifer – Hodder Mudstone Formation	High	Changes to groundwater quality due to accidental spillages at Bonstone Compound and Braddup Compound.	Temporary	Minor	Slight
Secondary A bedrock aquifer – Pendletone Formation; and Secondary A bedrock aquifers (Clitheroe Limestone, Hodder Mudstone Formation)	High	Changes to groundwater quality due to accidental spillages at Braddup Compound.	Temporary	Minor	Slight
PWS4-6	Medium	Changes to water quality due to accidental spillages.	Temporary	Moderate	Moderate– Significant
Whinny Lane East	Medium to low	Changes to water quality due to accidental spillages at Braddup Compound access track.	Temporary	Moderate	Moderate– Significant
Slaidburn Road West	Medium to low	Changes to water quality due to accidental spillages at Braddup Compound access track.	Temporary	Moderate	Moderate– Significant
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Changes to groundwater quality due to drainage from hard surfaces and car parks at office and welfare facilities.	Temporary	Minor	Slight
Secondary A bedrock aquifer – Hodder Mudstone Formation; and	High	Changes to groundwater quality due to drainage from hard surfaces and car	Temporary	Minor	Slight

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of impact	Significance of Effect (Pre-Mitigation)
Secondary A bedrock aquifers (Clitheroe Limestone, Hodder Mudstone Formation)		parks at office and welfare facilities.			

7.6.2 Construction Phase

128) The following provides an overview of the potential effects on the water environment as a result of the construction phase.

Fluvial Geomorphology

129) The construction phase of the Proposed Marl Hill Section would include the following activities which could interact with the watercourses identified in the fluvial geomorphology baseline:

- The discharge of construction drainage to surface water features
- Changes to flow regime due to temporary culvert crossings and site compound drainage
- Fine sediment increases during the operation of access routes
- Removal of temporary structures.

130) Without any specific mitigation (i.e. non-embedded mitigation), these activities would have the potential to cause the following which are described in more detail below:

- Increased fine sediment input
- Changes to flow regime
- Channel instability.

131) Dewatering of groundwater could also impact watercourses and is discussed in the groundwater section of this assessment.

<u>Increased Fine Sediment Input</u>

132) Whilst the access route at Braddup Compound would be in use, fine sediment could be mobilised and reach Sandy Ford Brook, Unnamed Watercourse 430 and Unnamed Watercourse 463. These watercourses exhibited a range of geomorphological features and processes which could be smothered by increased volumes of fine sediment. Therefore, the impact due to changes in supply of fine sediment would likely be moderate, with a moderate significance of effect.

133) Whilst the access route at Braddup Compound would be in use, fine sediment could be mobilised and reach Unnamed Watercourse 431 and Unnamed Watercourse 433. The geomorphological features on both of these watercourses were limited to cobble steps, which would be sensitive to changes in fine sediment input. Therefore, the impact on Unnamed Watercourse 431 and Unnamed Watercourse 433 of an increase in fine sediment input would likely be minor, with a slight significance of effect.

<u>Changes to Flow Regime</u>

134) Drainage (construction and surface water runoff) from Bonstone Compound would flow into Unnamed Watercourse 402 through a temporary outfall, which could change the flow regime and potentially cause erosion of the bed and opposite bank. The estimated greenfield runoff rate for the compound footprint would be 6.2 l/s. Discharge to Unnamed Watercourse 402 would be attenuated to 6 l/s, allowing for a maximum permissible discharge approximately 0.2 l/s less than would be encountered under baseline conditions. Therefore, there would likely be a negligible effect on the watercourse with a neutral significance.

135) Drainage (construction and surface water runoff) from Braddup Compound would flow into Sandy Ford Brook through a temporary outfall, which could change the flow regime and potentially cause erosion of the bed and opposite bank. The estimated greenfield runoff rate for the compound footprint would be 10 l/s. Discharge to Sandy Ford Brook would be attenuated to 9 l/s, allowing for a maximum permissible discharge approximately 1 l/s less than would be encountered under baseline conditions. Therefore, there would likely be a negligible effect on the watercourse with a neutral significance.

136) The culvert crossings for the access route to Braddup Compound would be extensions to the existing culverts. It is assumed that the culvert extensions would have the same cross-sectional area and shape

as the existing culverts, with the length of each culvert increasing by approximately 4 m which would likely have a minimal impact on baseline flow conditions. Therefore, the effect on the flow regime for Sandy Ford Brook, Unnamed Watercourse 430, Unnamed Watercourse 463, Unnamed Watercourse 431 and Unnamed Watercourse 433 would likely be negligible, with a neutral significance of effect.

Channel Instability

137) Sandy Ford Brook, Unnamed Watercourse 430 and Unnamed Watercourse 431 were seen to be stable during the site visit. Therefore, channel instability due to unsuitable reinstatement of bed and / or banks following the removal of the culverts would be unlikely. Culvert removal would likely have a negligible impact on these watercourses, with a neutral significance of effect.

138) Unnamed Watercourse 433 exhibited evidence of actively incising, whilst Unnamed Watercourse 463 showed evidence of extensive bank erosion downstream of the existing crossing. Unsuitable reinstatement of bed and / or banks following the removal of the temporary culvert could exacerbate this process and lead to channel destabilisation, and a change in the sediment regime downstream. This could lead to a moderate impact due to loss of integrity of the channel, with a moderate significance of effect.

139) As well as the removal of the temporary culverts, the access routes and compounds would be removed at the end of the construction phase. It is assumed that these areas would be returned to the baseline conditions with appropriate landscaping. Consequently, there would be a negligible impact on fluvial geomorphology, with a neutral significance of effect.

Surface Water Quality

140) During the construction phase of the Proposed Marl Hill Section, it is acknowledged that some activities highlighted in the enabling works phase, identified as having the potential to have an adverse impact on surface water quality, would continue to be applicable during the construction phase. These are:

- Topsoil stripping and earthworks related to all site construction activities as well as storage of soils on site
- Release of polluting substances (oils, fuels, chemicals and cement) from plant and machinery as well as storage
- The discharge of construction drainage to surface water features.

141) Other activities which are more exclusively linked to the construction phase include:

- Construction and sinking of two shafts within the northern Bonstone and southern Braddup Compounds and any (minimal) open-cut sections of tunnel that are required to link the Proposed Marl Hill Section to the existing aqueduct
- Reinstatement / demobilisation of construction site.

142) Without any specific mitigation (i.e. non-embedded mitigation), these activities during the construction works would have the potential to cause the following effects on water quality, which are described in more detail below:

- Sediment laden runoff
- Chemical pollution
- Bed and bank disturbance
- Impacts to surface water habitats.

Sediment Laden Runoff

143) The construction of two shafts, one located within the Bonstone and one within the Braddup Compounds, and (minimal) open-cut sections of pipe installation connecting to the existing aqueduct would have the potential to create impacts to surface water quality from sediment laden runoff. Whilst the access tracks

are in use there would be the potential for silt laden runoff from these areas to reach identified receiving watercourses, which may lead to increases in suspended solids and turbidity.

144) The temporary access tracks and compounds would be removed at the end of the construction phase. These areas would be returned to the baseline conditions with consideration of appropriate landscaping. Depending on the availability of the turfs for landscaping and the potential for bare soils, there could be the potential for silt laden runoff to enter receiving watercourses, impacting on surface water quality.

145) For the Bonstone Compound and associated access route this would have the potential to impact tributaries of the River Hodder (Foulscales Brook, Unnamed Watercourse 388 and Unnamed Watercourse 402). Furthermore, site drainage would be discharged to Unnamed Watercourse 402 from the Bonstone Compound.

146) As a result, the magnitude of impact would be minor for Unnamed Watercourse 388 and Unnamed Watercourse 402 which have a medium sensitivity. This would result in a slight significance of effect for these watercourses. Due to the increased distance from the construction activities and dilution effects the magnitude of impact for Foulscales Brook would likely be negligible for sediment laden runoff. This would result in a neutral significance of effect for this watercourse.

147) For the Braddup Compound and associated access route this would have the potential to impact tributaries of Bashall Brook (Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook, Cow Hey Brook, Unnamed Watercourse 444 and Unnamed Watercourse 463). Furthermore, site drainage would be discharged to Sandy Ford Brook from the Braddup Compound.

148) The magnitude of impact reported for all watercourses of medium and low sensitivity in relation to sediment laden runoff related to the Braddup Compound would be minor. This would result in a slight significance of effect for Sandy Ford Brook, Cow Hey Brook and Unnamed Watercourse 463 and a neutral significance of effect for Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433 and Unnamed Watercourse 444.

149) All scoped-in watercourses that are at the north of the Bonstone Compound flow into the River Hodder, through the Foulscales Brook. Due to the overall distance and dilution capacity of this watercourse and the River Hodder, the cumulative effect of sediment laden runoff would likely have a negligible magnitude of impact, resulting in a neutral significance of effect on the River Hodder.

150) Similarly, all scoped-in watercourses associated with the Braddup Compound flow in to Bashall Brook from several tributaries. Due to the overall distance from the site compound to Bashall Brook and the cumulative dilution capacity of the tributaries and Bashall Brook, the effect of sediment laden runoff on Bashall Brook would be negligible. This would result in a neutral significance of effect on Bashall Brook.

<u>Chemical Pollution</u>

151) During the construction phase, due to the presence (and movement via access routes) of plant along with use of potentially polluting substances, it would be expected that the same potential impacts would occur as those described in the enabling phase.

152) A minor magnitude of impact related to chemical pollution would be assigned to Unnamed Watercourse 388 and Unnamed Watercourse 402. This would result in a slight significance of effect for these watercourses. A negligible magnitude of impact for chemical pollution to the Foulscales Brook would be anticipated, resulting in a neutral significance of effect for this watercourse.

153) The magnitude of impact reported for all watercourses of medium and low sensitivity in relation to chemical pollution within the Bashall Brook catchment would be minor. This would result in a slight significance of effect for Sandy Ford Brook, Cow Hey Brook and Unnamed Watercourse 463 and a neutral significance of effect for Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433 and Unnamed Watercourse 444.

154) All scoped-in watercourses that are in the north of the Proposed Marl Hill Section flow into the River Hodder via the Foulscales Brook. Therefore, the cumulative effect of chemical pollution would likely have a negligible magnitude of impact, with a neutral significance of effect on the River Hodder.

155) Given the distance from the Braddup Compound to Bashall Brook and the associated dilution factors of both the Sandy Ford Brook and the Cow Hey Brook, the magnitude of impact from chemical pollution on Bashall Brook would be negligible. This would result in a neutral significance of effect for Bashall Brook.

Bed and Bank Disturbance

156) The culverts would be in use throughout the construction phase and may become damaged or not function as intended. This constant use can exert and / or exacerbate pressures on bed and banks of the watercourse leading to increases in turbidity and suspended solids. It is acknowledged that the potential pressures described above are not directly linked to a specific construction activity but are rather a symptom of them.

157) The removal of the temporary culverts could cause a short-term impact on surface water quality following the release of and disturbance to the bed and banks of the channel. This would increase turbidity and suspended solids decreasing water quality. It would be anticipated that the channel bed and banks would be restored to baseline conditions.

158) The magnitude of impact associated with bed and bank disturbance during construction would be expected to be the same as those reported during the enabling works phase where culverting is required. Consequently, the magnitude of impact of bed and bank disturbance on Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook, Cow Hey Brook and Unnamed Watercourse 463 would be minor. This would result in a slight significance of effect for Sandy Ford Brook, Cow Hey Brook and Unnamed Watercourse 463, whereas the significance of effect for Unnamed Watercourse 430, Unnamed Watercourse 431 and Unnamed Watercourse 433 would be neutral.

159) For near channel works anticipated on Unnamed Watercourse 402 and Unnamed Watercourse 444, the magnitude of impact of bed and bank disturbance would be reported as negligible. This would result in a neutral significance of effect for these watercourses.

Impacts to Surface Water Habitats

160) The same potential impacts to the area of Good Quality Semi-Improved Grassland would be present during the construction phase as outlined in the enabling works phase.

161) The magnitude of impact on the area of Good Quality Semi-Improved Grassland would be anticipated to be negligible resulting in a significance of effect of neutral.

Groundwater

162) The assessment of the potential effects of the construction phase of the Proposed Marl Hill Section on groundwater covers two areas: groundwater flow and groundwater quality.

Groundwater Flow

163) During construction, groundwater dewatering impacts could occur as a result of various activities, which are discussed in turn in more detail below:

- Shaft construction (total excavation depth taken into account)
- Tunnel construction
- Trench excavations associated with open cuts.

Shaft Construction

164) Given the proposed design activities related to installing the 15 m diameter launch and reception shaft structures (Bonstone Compound to 14 m bgl and Braddup Compound to 13.5 m bgl), there would be associated potential impacts due to dewatering of the surrounding aquifers during shaft construction, along with those associated with general construction activities. The dewatering impact would apply

only during shaft construction, with the shafts being fully sealed prior to the commencement of tunnelling.

165) At the time of writing, no groundwater-level data had been obtained for the Proposed Marl Hill Section. Therefore, a groundwater level of 1 m below ground surface was conservatively assumed for the purpose of the assessment. It is therefore assumed that groundwater level would be present in the superficial till deposits (medium sensitivity) at both the Bonstone Compound and the Braddup Compound. The shaft structures would be expected to encounter bedrock (high sensitivity) at both the Bonstone Compound and Braddup compound so a dewatering effect is expected at both locations.

166) The Sichardt method (e.g. Preene *et al.,* 2016)[16] was used to estimate the dewatering zone of influence around each of the shafts (launch and reception) that would be expected to intercept groundwater. This was applied using the estimated drawdown of groundwater levels to the base of the shaft during construction. The estimation accounted for the limited duration of open excavation associated with the proposed construction method by applying a 50 % reduction factor to the potential drawdown value. Hydraulic conductivity values used in the calculation were taken as generic values from scientific literature (Domenico and Schwartz, 1990)[17] representative of the materials as per the published geology and materials encountered during the construction of the existing aqueduct.

167) The zone of influence for both the Bonstone and Braddup Compound shafts estimated using the Sichardt method was small. The Sichardt method is considered to be unreliable for small values of the zone of influence. In order to ensure a suitable conservative assessment, a minimum zone of influence of 25 m was assumed and applied for both shafts in this case. The dewatering impacts would be localised in both the superficial and bedrock aquifers at both shaft locations, considered to be a minor magnitude at the scale of these aquifers, resulting in a significance of effect of slight in both the superficial aquifer and bedrock aquifers at both shaft locations.

168) As stated in Table 7.6 and Appendix 7.5, the exact location of PWS4-6, described as a spring of medium sensitivity, is unknown. It could be present within the Braddup Compound. To ensure a conservative assessment, it has been assumed that PWS4-6 is present at the shaft location. If PWS4-6 is present at the shaft location, the direct impact would result in a major magnitude of impact, resulting in a potential significance of effect of large.

169) No properties, listed buildings, scheduled monuments or other infrastructure have been identified within the zone of influence of either of the two shafts. Equally, no groundwater abstractions, no GWDTE, no surface water feature and no contaminated land would be located within the zone of influence of either of the two shafts.

170) The potential inflow of groundwater to the shafts during construction was estimated using the Darcy equation[18], for both horizontal inflow through the open walls of the excavation and the vertical inflow through the base. The same parameters were used as for the dewatering zone of influence calculations described above, with the effective hydraulic gradient based on the degree of drawdown and calculated zone of influence.

171) The maximum estimated inflows, within the superficial deposits, was 11.47 m^3/day for both shafts. With the shafts at their design total depth but before they would be sealed, estimated inflows were 0.58 and 0.48 m^3/day for Bonstone and Braddup compounds shafts respectively. These values are well below the Environment Agency's groundwater abstraction licencing threshold and consequently they would be exempt from licencing and the potential impact on the superficial and bedrock aquifers is considered to be minor, resulting in a potential significance of effect of slight in both bedrock aquifers at both shaft locations.

Tunnel Construction

172) The tunnel would be formed using a tunnel boring machine, with the tunnel continuously lined as the boring progresses. Daily progress would be expected to average approximately 10 m per day, with a

[16] Preene, M., Roberts, T.O.L. & Powrie, W. (2016) *op. cit.*
[17] Domenico, P.A. and Schwartz, F.W. (1990) *op. cit.*
[18] Describes the flow of a fluid through a porous medium.

maximum of 10 m open head (unlined) bedrock. Initial dewatering volume estimates were produced by United Utilities using parameters based on the anticipated construction method, along with review of available information on inflows encountered during construction of the existing Haweswater Aqueduct. The modelled average inflow for the Proposed Marl Hill Section is 1.20 l/s, with the likelihood that there would be short duration spikes in inflow (circa 5 l/s for up to a week, and circa 30 l/s for up to 36 hours).

173) Given the above, groundwater disturbances within bedrock would be expected to be minor, localised and temporary. As a result, any groundwater flow disturbance would be expected to be negligible at the scale of the aquifer, resulting in a potential significance of effect of neutral.

174) The only receptor that would be located in proximity to the tunnel is PWS4-3 located approximately 12 m west, which is described as a borehole of unknown depth. The depth of the tunnel at this location would be 37 m bgl. Given the uncertainties and proximity to the tunnel, potential impacts cannot be ruled out. Aerial photographs could not confirm the location of this supply. Provided the borehole supporting PWS4-3 is located where suggested, short-lived potential impacts could affect supply. This is assessed as a potential moderate magnitude impact, resulting in a potential moderate significance of effect.

175) No impact is expected on surface receptors such as surface waters and GWDTEs.

Other Flow Disruption Impacts

176) The other works that would be expected to involve excavation of the ground surface during the construction phase are the connections (i.e. connecting to the existing aqueduct at either end of the Proposed Marl Hill Section tunnel) and the overflow at the Braddup Compound. These works are expected to require excavations of up to 5 m deep and 5 m wide for single connections and 50 m wide for multi-line connections.

177) Due to the absence of any groundwater-level data, a conservative estimate of groundwater level (1 m bgl) has been assumed at both the Bonstone Compound and Braddup Compound. The dewatering of all excavations would therefore be expected to generate a localised minor potential magnitude of impact, resulting in a potential significance of effect of slight on superficial deposit aquifers.

178) The connection and overflow excavations are not expected to encounter the bedrock of the Hodder Mudstone at any of the excavation locations, therefore no dewatering effect would be expected on the bedrock and so no impact has been assessed.

179) The Sichardt method (e.g. Preene *et al.*, 2016)[19] was used to estimate the dewatering zone of influence around each excavation that would be expected to intercept groundwater. This was applied using the estimated drawdown of groundwater levels to the base of the excavation. Hydraulic conductivity values used in the calculation were taken as generic values from scientific literature (Domenico and Schwartz, 1990)[20] representative of the materials as per the published geology and materials encountered during the construction of the existing aqueduct.

180) Where the zone of influence estimated using the Sichardt equation is quite small, the method is considered to be unreliable. Therefore, in order to ensure a suitable conservative assessment, a minimum zone of influence of 25 m has been assumed and applied for the connections at the Bonstone Compound and Braddup Compound, and the overflow construction at the Braddup Compound.

181) A review of impacts to potential receptors comprising PWS, GWDTEs, surface water, infrastructure and buildings, cultural heritage sites, and contaminated land sites are presented in Appendix 7.5 conducted using calculated zones of influence for each feature. The review is based on the understanding of geology from published BGS maps and the geology encountered during the construction of the existing aqueduct, and a conservative estimate of the groundwater level across the Proposed Marl Hill Section.

182) Unnamed Watercourse 402 (medium sensitivity) is the only surface water feature which could be potentially impacted by dewatering at the Bonstone Compound during this phase of works, lying within the zone of influence of groundwater drawdown from the proposed aquifer connection. However, as

[19] Preene, M., Roberts, T.O.L. & Powrie, W. (2016) *op. cit.*
[20] Domenico, P.A. & Schwartz, F.W. (1990) *op. cit.*

described, it would be expected that the abstracted water be returned to the Unnamed Watercourse 402 immediately downgradient of the works, resulting in a potential magnitude of impact of minor and a significance of effect of neutral.

183) Cow Hey Brook is the only surface water feature which could be potentially impacted by dewatering at the Braddup Compound during this phase of works, lying within the zone of influence of groundwater drawdown from the proposed overflow. However, as described in Appendix 7.6, it would be expected that the abstracted water be returned to the Cow Hey Brook immediately downgradient of the works. Cow Hey Brook is also present within the Braddup Compound footprint, so that there could be indirect effects due to ground disturbance and compaction. The resulting potential magnitude of impact is assessed as minor, resulting in a potential significance of effect of slight. Further information, including the relevant assessments of significance of effect for each feature, is presented in Appendix 7.6.

184) In terms of infrastructure, the access track to the single property in the vicinity of the Braddup Compound would be expected to be impacted by the connection and overflow excavations at the Braddup Compound. However, as both the connection and overflow excavations would cut directly across the access track, the main impact would be physical disruption rather than as a result of dewatering impacts. Therefore, no specific groundwater impact has been assessed.

185) There is uncertainty about the exact location of PWS4-6 within the Braddup Compound. Should PWS4-6 be present at the location of the open-cut connection or overflow, it could be directly impacted (major magnitude) which could result in a large potential significance of effect.

186) Also, there is a large uncertainty on the network associated with PWS4-4 and PWS4-1 distributing respectively through the Colthurst and the Knowlmere estates. Part of the infrastructure could be directly impacted (major magnitude) which could result in a large potential significance of effect.

187) No impacts to buildings, cultural heritage sites, other infrastructure or contaminated land sites would be expected during this phase of works.

188) Potential significant impacts due to overflow and connection construction on groundwater flows supporting GWDTEs are summarised in Table 7.20. Disruption to groundwater flows supporting GWDTEs could also occur due to ground compaction caused by heavy haulage vehicles and plant using the temporary access tracks. Potential significant impacts due to ground compaction are also summarised in Table 7.20. All potential impacts on groundwater levels and flows in the refined GWDTE assessment area are discussed in detail in Appendix 7.2.

Table 7.20: Summary of Significant Impacts to GWDTEs

Site Name	Sensitivity	Activity / Effect	Magnitude of Impact	Significance of Effect
Braddup House	Low	Braddup open-cut connection dewatering (groundwater levels / flows)	Major	Large– Significant
		Braddup overflow dewatering (groundwater levels / flows)	Major	Large– Significant
Whinny Lane East	Medium to low	Intercept flows in short term due to ground compaction (groundwater levels / flows)	Major	Large– Significant
Slaidburn Road West	Medium to low	Intercept flows in short term due to ground compaction (groundwater levels / flows)	Major	Large– Significant

Groundwater Quality

189) Ground disturbance from earthworks associated with shaft construction and open-cut areas would potentially cause changes to groundwater quality due to mobilisation of soil and rock particles

(suspended solids) which would migrate through sub-soil and affect adjacent sensitive receptors (e.g. shallow groundwater abstractions and GWDTEs).

190) As per Table 7.1, potential impacts on aquifers from silt contamination have been scoped out.

191) Considering the CCoP (Appendix 3.2), which already refers to embedded mitigation measures associated with controlling silt pollution, groundwater receptors potentially impacted by the ground disturbance effects from earthworks would be PWS and GWDTEs. The assessment of these effects on groundwater receptors are provided in Table 7.21.

Table 7.21: Potential Impact of Ground Disturbance from Earthworks on Key Hydrogeological Receptors

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
PWS4-6, spring	Medium	Moderate	Could be present anywhere within the Braddup Compound, including southern access road envelope and could be impacted as the access road gets utilised.	Moderate–Significant
All other PWS are not considered to be impacted during the construction phase of works.				
All GWDTEs are expected to receive effects with a slight or neutral significance of effect or receive no impacts.				

192) The CCoP (Appendix 3.2) also indicates that soil storage areas would be lined, ensuring that runoff is captured and there is no infiltration to the ground.

193) The CCoP (Appendix 3.2) refers to guidance on pollution prevention measures which would be followed, along with setting up methodologies associated with fuel storage, and storage of materials and waste. This would include the development of a Construction Environmental Management Plan. These embedded mitigation measures would reduce significantly the risks to groundwater quality impairment and associated receptors resulting from accidental spillages. The assessment of accidental spillages during this phase (i.e. associated with open-cut sections, shaft construction, access roads and tunnel construction) on these aquifers and relevant receptors is provided in Table 7.22 taking into account the embedded measures recorded in the CCoP (Appendix 3.2). Further details on impacts to groundwater quality at GWDTE sites due to accidental spillages is provided in Appendix 7.2.

Table 7.22: Potential Impact of Accidental Spillages on Key Hydrogeological Receptors

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Minor	Present at the Bonstone Compound and access road, and Braddup Compound and access road.	Slight
Secondary A superficial aquifer - river terrace deposits	High	Negligible	Present 140 m south-west of Bonstone Compound	Neutral
Secondary A bedrock aquifer – Hodder Mudstone Formation	High	Minor	Present at the0 Bonstone Compound and proposed Braddup Compound.	Slight

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
Secondary A bedrock aquifer – Pendletone Formation	High	Minor	Present at the south-west corner of the Braddup Compound.	Slight
Secondary A bedrock Aquifer – Clitheroe Limestone and Hodder Mudstone Formation	High	Minor	Present at the eastern half of the Braddup Compound and access road.	Slight
PWS4-6, spring	Medium	Moderate	Could be present anywhere within the Braddup Compound, including southern access road envelope and could be impacted as the access road gets utilised.	Moderate–Significant
All other PWS are not considered to be impacted during the construction phase of works.				
All GWDTEs are expected to receive effects with a slight or neutral significance of effect or receive no impacts.				

Summary of Effects

194) A summary of the construction phase effects is shown in Table 7.23.

Table 7.23: Summary of Construction Phase Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
Sandy Ford Brook (W530)	High	Increased fine sediment input	Temporary	Moderate	Moderate– Significant
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Negligible	Neutral
Unnamed Watercourse 430 (W520)	High	Increased fine sediment input	Temporary	Moderate	Moderate– Significant
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Negligible	Neutral
Unnamed Watercourse 402 (W483)	Medium	Changes to flow regime	Temporary	Negligible	Neutral
Unnamed Watercourse 431 (W521)	Medium	Increased fine sediment input	Temporary	Minor	Slight
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Negligible	Neutral
Unnamed Watercourse 433 (W523)	Medium	Increased fine sediment input	Temporary	Minor	Slight
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Moderate	Moderate– Significant
Unnamed Watercourse 463 (W557)	Medium	Increased fine sediment input	Temporary	Moderate	Moderate– Significant
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Moderate	Moderate– Significant

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Surface Water Quality					
River Hodder (W477)	Very high	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Tributary of the River Hodder; Unnamed Watercourse W466	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
Tributary of the River Hodder; Unnamed Watercourse W483	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
		Bed and bank disturbance	Temporary	Negligible	Neutral
Foulscales Brook (W465)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Bashall Brook	High	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Tributaries of Bashall Brook; W530 (Sandy Ford Brook), W535 (Cow Hey Brook) and W557.	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
		Bed and bank disturbance	Temporary	Minor	Slight
Tributaries of Bashall Brook; W520, W521, W523, W536	Low	Sediment laden runoff	Temporary	Minor	Neutral
		Chemical pollution	Temporary	Minor	Neutral
		Bed and bank disturbance	Temporary	Minor	Neutral
Good Quality Semi-Improved Grassland (SD7001448596)	Medium	Impact to surface water dependent habitat	Temporary	Negligible	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Groundwater					
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Localised drawdown of the water table around shafts, connection and overflow excavations at Bonstone and Braddup compounds	Temporary	Minor	Slight
Secondary A bedrock aquifers (Clitheroe Limestone, Hodder Mudstone Formation)	High	Localised drawdown of the water table around shafts, connection and overflow excavations at Bonstone and Braddup compounds	Temporary	Minor	Slight
Secondary A bedrock aquifers (Pendleside Limestone Formation, Hodderense Limestone Formation, Hodder Mudstone Formation, Marl Hill Shale Formation, Pendleton Formation)	High	Disturbance to groundwater flow from the construction of the tunnel	Temporary	Negligible	Neutral
PWS4-3 (borehole)	Medium	Reduced capacity or loss of resource due to disturbance to groundwater flow from the construction of the tunnel	Temporary	Moderate	Moderate– Significant
Unnamed Watercourse 402 (W483)	Medium	Reduced contribution to baseflow due to dewatering for connection construction at Bonstone Compound	Temporary	Minor	Neutral
Cow Hey Brook	Medium	Reduced contribution to baseflow due to dewatering for overflow construction at Braddup Compound	Temporary	Minor	Slight

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Braddup House	Low	Localised drawdown of the water table around connection excavation at Braddup Compound	Temporary	Major	Large– Significant
		Localised drawdown of the water table around overflow excavation at Braddup Compound	Temporary	Major	Large– Significant
Whinny Lane East	Medium to low	Intercept flows in short term due to ground compaction (groundwater levels / flows)	Temporary	Major	Large– Significant
Slaidburn Road West	Medium to low	Intercept flows in short term due to ground compaction (groundwater levels / flows)	Temporary	Major	Large– Significant
PWS4-4 and PWS4-1	Medium	Potential direct impact on network	Permanent	Major	Large– Significant
PWS4-6 (spring)	Medium	Potential direct impact on spring PWS	Permanent	Major	Large– Significant
		Changes to water quality due to ground disturbance from earthworks and construction works	Temporary	Moderate	Moderate– Significant
		Changes to water quality due to accidental spillage during construction works	Temporary	Moderate	Moderate– Significant

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Secondary Undifferentiated superficial Aquifer – glacial till (diamicton)	Medium	Changes to groundwater quality due to accidental spillages at Bonstone and Braddup compounds and access roads	Temporary	Minor	Slight
Secondary A superficial aquifer – river terrace deposits	High	Changes to groundwater quality due to accidental spillages at Bonstone Compound	Temporary	Negligible	Neutral
Secondary A bedrock aquifer (Hodder Mudstone Formation)	High	Changes to groundwater quality due to accidental spillages at Bonstone and Braddup compounds	Temporary	Minor	Slight
Secondary A bedrock Aquifers (Pendletone Formation, Clitheroe Limestone Formation)	High	Changes to groundwater quality due to accidental spillages at Braddup Compound	Temporary	Minor	Slight

7.6.3 Commissioning Phase

195) The following provides an overview of the potential effects on the water environment as a result of the commissioning phase.

Fluvial Geomorphology

196) During the commissioning phase of the Proposed Marl Hill Section there would be a discharge of flows from the aqueduct.

197) Without any specific mitigation (i.e. non-embedded mitigation), the above activity would have the potential to cause changes to the flow and sediment transport regimes, which has been described in more detail below.

<u>Changes to Flow and Sediment Transport Regimes</u>

198) At the north end of the Proposed Marl Hill Section, commissioning flows would discharge into Unnamed Watercourse 402. This would be through the temporary outfall used for construction drainage and surface water runoff from Bonstone Compound. The discharge would be at a rate of 25 l/s, which is likely to be higher than baseline flows in the watercourse, given its size and the discharge of water at the head of the watercourse.

199) Although no bank erosion was observed on Unnamed Watercourse 402, the commissioning flows would likely have the potential to trigger erosion of the bed and opposite bank. In addition, fine sediment volumes may increase as a result of both increased bank erosion and entrainment of bed substrate, potentially smothering downstream features. Therefore, the commissioning flows would likely have a major magnitude of impact on the watercourse with a moderate significance of effect.

200) At the south end of the Proposed Marl Hill Section, commissioning flows would discharge into Sandy Ford Brook. This would be through the temporary outfall used for construction drainage and surface water runoff from Braddup Compound. The discharge would be at a rate of 25 l/s. Bank erosion was seen on the bank opposite the proposed outfall location and further downstream, which could be exacerbated by the commissioning flows. In addition, fine sediment volumes may increase as a result of both increased bank erosion and entrainment of bed substrate, potentially smothering downstream features. Therefore, the commissioning flows would likely have a major magnitude of impact on the watercourse with a large significance of effect.

Surface Water Quality

201) During the commissioning phase of the Proposed Marl Hill Section, the following activities have been identified as having the potential to impact on watercourses identified in the surface water quality baseline:

- The discharge of untreated commissioning flows to surface water features
- Bank disturbance from commissioning flow discharges
- Establishing a secure and isolated transfer of commissioning flows to attenuation ponds.

202) Without any specific mitigation (i.e. non-embedded mitigation), these activities during the commissioning works would have the potential to cause the following effects on surface water quality, which are described in more detail below:

- Discharge of untreated commissioning flows
- Bank disturbance.

<u>Discharge of Untreated Commissioning Flows</u>

203) As part of the commissioning works there would be a requirement for the transfer of chlorinated water from the existing aqueduct through a dechlorination plant to two or more attenuation ponds prior to discharge to surface water receptors. Ensuring the commissioning flows are transferred between existing

aqueduct and attenuation without any leakage would prevent untreated water potentially leaving the site. Furthermore, any potential increases in sediment laden runoff (causing increases in turbidity, affecting pH and increasing suspended solids) and chemical pollution issues relating to uncontrolled release of chlorinated water would be mitigated if the transfer of flows is contained and secure. Any leakage of commissioning flows would be anticipated to be limited to site drainage discharge locations, potentially impacting Unnamed Watercourse 402 (and downstream tributaries Foulscales Brook and Unnamed Watercourse 388) and Sandy Ford Brook.

204) Furthermore, it would be assumed the attenuation ponds would be sized to allow appropriate retention time for settlement prior to discharge of dechlorinated water. Should this not be the case, or the treatment system fails, the discharge of chlorinated commissioning flows would likely alter baseline water chemistry and degrade surface water quality in Unnamed Watercourse 402 and Sandy Ford Brook. To a lesser extent commissioning discharges could have the potential to effect downstream tributaries of Unnamed Watercourse 402, namely Foulscales Brook and Unnamed Watercourse 388, located within the assessment area.

205) As a result, the magnitude of impact would be minor for Unnamed Watercourse 388 and Unnamed Watercourse 402. Due to the combined dilution factor and overall distance from the discharge location to Foulscales Brook the magnitude of impact would be negligible for discharge of untreated commissioning flows. This would result in a slight significance of effect for Unnamed Watercourse 388 and Unnamed Watercourse 402 and a neutral significance of effect for Foulscales Brook. The equivalent magnitude of impact reported for Sandy Ford Brook would be minor. This would result in a slight significance of effect.

<u>Bank Disturbance</u>

206) The discharge of commissioning flows from attenuation ponds to receiving watercourses could have the potential to destabilise banks and may lead to increases in turbidity, affect pH and increase suspended solids.

207) Given the proposed rate of discharge of these commissioning flows (approximately 25 l/s) the magnitude of impact from bank disturbance on water quality on Unnamed Watercourse 402 and Sandy Ford Brook would be minor. This would result in a slight significance of effect for these watercourses.

208) As a consequence of the catchment connectivity and dilution factors associated with the downstream tributaries, namely the Foulscales Brook and Unnamed Watercourse 388, the magnitude of impact from these discharges to bank disturbance would be negligible. This would result in a neutral significance of effect for these watercourses.

Groundwater

209) No impacts would be expected on groundwater during the commissioning phase.

Summary of Effects

210) A summary of the commissioning phase effects is shown in Table 7.24.

Table 7.24: Summary of Commissioning Phase Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
Sandy Ford Brook (W530)	High	Changes to flow and sediment transport regimes	Temporary	Moderate	Large– Significant
Unnamed Watercourse 402 (W483)	Low	Changes to flow and sediment transport regimes	Temporary	Major	Moderate– Significant
Surface Water Quality					
Tributary of the River Hodder: Unnamed Watercourse W483	Medium	Discharge of untreated commissioning flows	Temporary	Minor	Slight
		Bank disturbance	Temporary	Minor	Slight
Tributary of the River Hodder: Unnamed Watercourse W466	Medium	Discharge of untreated commissioning flows	Temporary	Minor	Slight
		Bank disturbance	Temporary	Negligible	Neutral
Tributary of the River Hodder: Foulscales Brook (W465)	Medium	Discharge of untreated commissioning flows	Temporary	Negligible	Neutral
		Bank disturbance	Temporary	Negligible	Neutral
Tributary of Bashall Brook: Sandy Ford Brook (W530)	Medium	Discharge of untreated commissioning flows	Temporary	Minor	Slight
		Bank disturbance	Temporary	Minor	Slight
Groundwater					
No impacts would be expected on groundwater during the commissioning phase.					

7.6.4 Operational Phase

211) The following provides an overview of the potential effects on the water environment as a result of the operational phase.

Fluvial Geomorphology

212) The operational phase of the Proposed Marl Hill Section would include the following activities which could interact with the watercourses identified in the fluvial geomorphology baseline:

- The discharge of permanent access route drainage to surface water features
- Operational discharge from the Proposed Marl Hill Section at the overflow.

213) Without any specific mitigation (i.e. non-embedded mitigation), the outlined activities would have the potential to cause changes to flow regime, which is described further below.

Changes to Flow Regime

214) The overflow from the Proposed Marl Hill Section aqueduct would discharge at the existing outfall location on Bashall Brook. The discharge of water during the operation of the aqueduct would be the same as the operational regime for the existing aqueduct (i.e. emergency discharges as required). Operational discharges from the existing aqueduct would stop and be replaced by discharges from the Proposed Marl Hill Section. Therefore, there would be no change from baseline condition, and the impact would likely be negligible, with a neutral significance of effect.

Surface Water Quality

215) The operational phase of the Proposed Marl Hill Section would include the following activities which could have the potential to interact with the watercourses identified in the surface water quality baseline:

- Use of permanent access tracks
- Release of polluting substances (oil, fuels, chemicals)
- Operational discharges.

216) Despite embedded mitigation measures, these activities would have the potential to cause the following effects on surface water quality, which are described in more detail below:

- Sediment laden runoff
- Chemical pollution
- Operational discharges.

Sediment Laden Runoff

217) Permanent access would be required to the new valve houses within the Proposed Marl Hill Section for maintenance. Sources of sediment laden runoff during the operational phase would be greatly reduced compared to the enabling and construction phases.

218) Access to the north end of the Proposed Marl Hill Section would make use of the existing access track, across the agricultural fields. Access would comprise of a gravel running surface. Providing that this access track would not require upgrading or widening, there would be no change from the baseline conditions.

219) The magnitude of impact on the Foulscales Brook, Unnamed Watercourse 388 and Unnamed Watercourse 402 would be negligible, resulting in a neutral significance of effect.

220) Access to the south end of the Proposed Marl Hill Section would make use of an existing access track, stemming from Slaidburn Road. Providing that this access track would not require upgrading or widening, there would be no change from the baseline conditions.

221) The magnitude of impact reported for all watercourses of medium and low sensitivity would be negligible. This would result in a neutral significance of effect for Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook, Cow Hey Brook, Unnamed Watercourse 444 and Unnamed Watercourse 463.

Chemical Pollution

222) There could be requirements for the ongoing use of potentially polluting substances during the operational phase as part of ongoing maintenance requirements. Any substance which could have the potential to cause chemical pollution, either imported, used, or stored on site, would be subject to environmental best practice and guidance, similar to the protocols in force during the construction phase.

223) The magnitude of impact on surface water quality from chemical pollution during the operational phase for watercourses Foulscales Brook, Unnamed Watercourse 388, Unnamed Watercourse 402, Unnamed Watercourse 430, Unnamed Watercourse 431, Unnamed Watercourse 433, Sandy Ford Brook, Cow Hey Brook, Unnamed Watercourse 444 and Unnamed Watercourse 463 would be negligible and would result in a neutral significance of effect for these watercourses.

Operational Discharges

224) The overflow from the Proposed Marl Hill Section would discharge at the existing outfall on the Bashall Brook. The water discharged at this location would be licenced and similar to that of the existing aqueduct, being used only in emergencies, as and when required. Operational discharges could have the potential to cause local erosion issues which could lead to increased turbidity downstream of the outfall location on Bashall Brook. Due to the limited number, and time period between operational discharges from the Proposed Marl Hill Section on Bashall Brook, the magnitude of impact would be negligible, resulting in a neutral significance of effect.

Groundwater

Permanent Shaft Structure on Groundwater Flows

225) Given the proposed shaft design diameter (15 m) and depth (Bonstone Compound at 14.0 m bgl and Braddup Compound at 13.5 m bgl), long-term groundwater disturbances would be expected to be negligible. As a result, any impact is predicted to be negligible for both the superficial and bedrock aquifers at both shaft locations, resulting in a potential significance of effect of negligible.

226) No other receptor would be expected to be impacted.

Permanent Tunnel Structure on Groundwater Flows

227) Given the Proposed Marl Hill Section tunnel design depth and dimensions (diameter of 3 m) and the fact the tunnel would be sealed, groundwater disturbances would be expected to be negligible at the scale of the aquifers, resulting in a negligible potential significance of effect for both superficial deposit and bedrock aquifers.

228) As during the construction phase, the only receptor located in proximity of the tunnel is PWS4-3, which is described as a borehole, although this has not been verified. The depth of the tunnel at this location would be 37 m and it is likely to be located upgradient from the PWS source. Provided the borehole supporting PWS4-3 is located where suggested, long-term impacts would be unlikely to be significant but cannot be ruled out. This is assessed as a potential minor magnitude, resulting in a potential slight significance of effect.

229) No impacts would be expected on surface receptors such as surface waters and GWDTEs.

Groundwater Quality

230) With limited activity and vehicle movement during operation, accidental spillages during the operational phase would result in a potential negligible magnitude of impact on groundwater aquifers and associated receptors. This would result in a neutral potential significance of effect.

Summary of Effects

231) A summary of the operational phase effects is shown in Table 7.25.

Table 7.25: Summary of Operational Phase Effects

Environmental / Community Asset	Value / Sensitivity	Effect	Duration	Magnitude	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
Bashall Brook (W556)	High	Changes to flow regime	Permanent	Negligible	Neutral
Surface Water Quality					
Tributaries of the River Hodder: Foulscales Brook (W465), W466 and W483	Medium	Sediment laden runoff	Permanent	Negligible	Neutral
		Chemical pollution	Permanent	Negligible	Neutral
Bashall Brook (W556)	High	Operational discharges	Permanent	Negligible	Neutral
Tributaries of Bashall Brook: W530 (Sandy Ford Brook), W535 (Cow Hey Brook) and W557	Medium	Sediment laden runoff	Permanent	Negligible	Neutral
		Chemical pollution	Permanent	Negligible	Neutral
Tributaries of Bashall Brook: W520, W521, W523 and W536	Low	Sediment laden runoff	Permanent	Negligible	Neutral
		Chemical pollution	Permanent	Negligible	Neutral
Groundwater					
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Disturbance to groundwater flow due to permanent shaft structures	Permanent	Negligible	Neutral
		Disturbance to groundwater flow due to permanent tunnel	Permanent	Negligible	Neutral
Secondary A bedrock aquifers (Clitheroe Limestone, Hodder Mudstone Formation)	High	Disturbance to groundwater flow due to permanent shaft structures	Permanent	Negligible	Neutral

Environmental / Community Asset	Value / Sensitivity	Effect	Duration	Magnitude	Significance of Effect (Pre-Mitigation)
Secondary A bedrock aquifers (Pendleside Limestone Formation, Hodderense Limestone Formation, Hodder Mudstone Formation, Marl Hill Shale Formation, Pendleton Formation)	High	Disturbance to groundwater flow due to permanent tunnel	Permanent	Negligible	Neutral
PWS4-3 (borehole)	Medium	Reduction in resource capacity due to disturbance to groundwater flow due to permanent tunnel	Permanent	Minor	Slight
Secondary Undifferentiated superficial aquifer – glacial till (diamicton)	Medium	Changes to groundwater quality due to accidental spillages at Bonstone and Braddup compounds	Temporary	Negligible	Neutral
Secondary A bedrock aquifers (Clitheroe Limestone, Hodder Mudstone Formation)	High	Changes to groundwater quality due to accidental spillages at Bonstone and Braddup compounds	Temporary	Negligible	Neutral

7.6.5 Decommissioning Phase

232) Following completion and commissioning of the Proposed Marl Hill Section, the existing sections of aqueduct would be taken out of service. A future maintenance and usage strategy for the redundant sections of aqueduct is being prepared. Current design proposals indicate that the existing section of aqueduct would be left in situ and would not be grouted or sealed once the Proposed Marl Hill Section has been commissioned. Therefore, it is likely that groundwater would enter the decommissioned aqueduct over time.

233) The existing aqueduct creates a flow pathway for groundwater ingress to reach the surface through the redundant tunnel structure. It is proposed this groundwater ingress would be discharged to Bashall Brook through the existing outfall location (at approximately E:370127 N:444224). This outfall would remain in place after the commissioning of the Proposed Marl Hill Section.

Fluvial Geomorphology

234) During the decommissioning phase of the Proposed Marl Hill Section the only activities which would interact with watercourses identified within the fluvial geomorphology baseline would be discharge of groundwater ingress from the existing overflow structure. Dewatering of groundwater could also impact watercourses and is discussed in the groundwater section of this assessment.

235) Without any specific mitigation, the discharge of groundwater ingress from the existing overflow structure would have the potential to cause changes to flow and sediment transportation regimes on Bashall Brook.

Changes to Flow and Sediment Transportation Regimes

236) Groundwater ingress from the existing aqueduct would be discharged at the existing outfall location on Bashall Brook once it has been decommissioned. The estimated groundwater ingress rate (based on upper limit 95%ile) is 26.5 l/s, which United Utilities have estimated based on observations made during inspections carried out in 2016. A Monte Carlo analysis[21] was also carried out to assess how this rate could increase over time. Further information relating to assumptions and limitations of this dataset are set out in Section 7.4.3.

237) Discharge of groundwater ingress would coincide with any discharge required for the operation and maintenance of the Proposed Marl Hill Section aqueduct at the same location.

238) Table 7.26 shows that the decommissioned flow would not have a significant impact on the specific stream power of Bashall Brook. For context, a river with a specific stream power of less than 10 W/m^2 at bankfull flow would be typical of a stable lowland watercourse. Bankfull specific stream powers between 10 and 300 W/m^2, as seen on the Bashall Brook, would be typical on watercourses that experience adjustment, often in response to changes in fluvial features or processes. Specific stream power is typically used for analysis of bankfull but has also been used here as an indicator of the potential impacts during low flow conditions.

Table 7.26: Bashall Brook Specific Stream Power

Flow Percentile	Specific Stream Power - ω (W/m^2)	
	Baseline	Decommissioning Phase
Q95	0.3	1.1
Q50	1.8	2.5
Qmed (bankfull)	186.9	187.7

239) Additional analysis of the sediment entrainment capability of Bashall Brook shows that there would be changes in the grain size of sediment transported following decommissioning. This would be limited to

[21] The use of randomness to solve a problem

lower magnitude flow events (i.e. Q70[22] and below) which would be more capable of entraining larger sediments than is currently the case. Specifically, Q95 flows would be capable of entraining fine gravels (currently capable of entraining very fine gravels), and Q70 flows would be capable of entraining medium gravels (currently capable of entraining fine gravels).

240) Change in flow would have an impact on the hydrological conditions in Bashall Brook, with the magnitude of more frequent events increasing, as presented in Table 7.27 (i.e. the current Q70 would become the future Q95, and the current Q50 would become the future Q70).

Table 7.27: Baseline and Decommissioning Flow Comparisons

Flow Percentile	Discharge (m^3/s)	
	Baseline	Decommissioning Phase
Q95	0.01	0.04
Q75	0.03	0.06
Q50	0.06	0.09
Q10	0.35	0.38
Qmed (bankfull)	6.37	6.40

241) Changes to flow and sediment transportation regimes on Bashall Brook would likely result in an increase in the volume of sediment being transported downstream, as well as reducing the opportunity for replenishment of depositional features such as bars and berms during low flow events. It is also likely that depths and velocities would be changed, which would likely cause localised changes in geomorphological processes. Therefore, discharge of groundwater ingress during the decommissioning phase would likely have a major effect on Bashall Brook, with a large significance of effect.

Dewatering

242) Impacts related to dewatering of watercourses is covered in the groundwater section of this assessment.

Surface Water Quality

243) During the decommissioning phase of the Proposed Marl Hill Section the only activity which would interact with watercourses identified within the surface water quality baseline would be discharge of groundwater ingress from the existing overflow structure.

244) Without any specific mitigation, the discharge of groundwater ingress from the existing overflow structure would have the potential to cause exceedances of water quality standards in the receiving watercourse. This is further explained below.

Exceedances of Water Quality Standards

245) The discharge of groundwater ingress from the existing aqueduct could have the potential to be polluted with a range of potential contaminants related to natural bedrock geology and current and historical land uses. Should groundwater be contaminated and discharged to Bashall Brook there would be the potential to impact surface water quality downstream of the existing outfall.

246) Due to the uncertainty of groundwater quality in the area around the Proposed Marl Hill Section, the magnitude of impact on surface water quality from decommissioning discharges to Bashall Brook would be moderate resulting in a significance of effect of moderate. Therefore, additional mitigation has been outlined in Section 7.7.

[22] Percentile flow. Q95: flow that exceeded 95% of the time. Q70: flow that exceeded 70% of the time. Q50: flow that exceeded 50% of the time

Groundwater

247) Following the commissioning of the Proposed Marl Hill Section, the existing aqueduct would be retained. Ingress into the existing aqueduct would be likely to occur over time. United Utilities has undertaken a modelling exercise to predict potential ingress volumes by 2055 as the aqueduct deteriorates. This estimation does not consider the geological settings and therefore, in low permeability areas, the natural geological properties could act as a more stringent limitation factor.

248) The United Utilities modelling predicted ingress rates of 15.28 l/s to 26.49 l/s for the entire existing Marl Hill section, which is about 4.3 km long, equating to an ingress rate of 3.57E-03 l/s/m to 6.19E-03 l/s/m. The surrounding geological settings comprising predominantly of siltstone and mudstone would be expected to generate a minor and localised effect. Although the sandstones of the Pendleton Formation and Pendleside Sandstone Member of the Bowland Shale Formation in the middle of the route would be expected to be of higher hydraulic conductivity, the tunnel is at greater depth in this area than in the north and south of the Marl Hill section.

249) There are two sections – a conduit at the northern end, from the Bonstone Compound to chainage 465 m, and tunnel at the southern end, from chainage 3390 m to the Braddup Compound – where the existing aqueduct is shallow. Period construction drawings[23] record these as being placed almost entirely within superficial deposits, typically described as 'Boulder Clay'. Recorded depths are between 2 m and 7 m in the north and 5 m and 41 m in the south, to the base of the conduit / tunnel.

250) In order to evaluate the potential of the predicted inflows to cause groundwater drawdown effects around the decommissioned aqueduct, simple 2D modelling of several representative cross-sections was carried out using SEEP/W software.[24] In the absence of available GI, generic literature hydraulic conductivity values were used in the SEEP modelling (Domenico & Schwartz, 1990).[25] Boundary conditions were set based on radii of influence calculated from the United Utilities modelled inflow rates. As described in the baseline, the exact depth to groundwater around the existing aqueduct is not known and, therefore, was conservatively assumed to be shallow, at 1 m bgl.

251) This chapter utilises data from various technical reports, and as a result includes reference to chainage throughout the assessment as a way of identifying the location of a feature or a point of interest as these are used within the technical reports. The chainage is the distance in metres from the northern extent of the Proposed Marl Hill Section (e.g. ch.2500 is 2,500 m from the start of the section).

252) The SEEP modelling predicted potential groundwater drawdowns of up to around 4.5 m along the northern conduit section (chainage 0 m to 465 m approximatively), then around 1 m at the northern end of the tunnel (chainage 465 m to 2560 m approximatively), and again 4.5 m to 3 m around the central and southern tunnel section (chainage 2560 m to 3765 m). It should be noted that this SEEP/W methodology is simplistic and high level to provide an order of magnitude indication of drawdown impacts. It is based on averaged parameters which would vary spatially (such as permeability) and focuses on a long-term prediction once the existing aqueduct has significantly deteriorated. The modelling, however, does not cover any potential collapse scenario.

253) In the northern tunnel section (chainage 465 m to 2560 m approximatively), the tunnel being quite deep at approximatively 90 m, the drawdown effect is expected to attenuate through the geological layering and be of no significance to surface receptors. On the other hand, the dewatering effect is expected to affect surface and sub-surface receptors in the northern conduit section (chainage 0 m to 465 m approximatively) and the central and southern tunnel section (chainage 2560 m to 3765 m).

254) The dewatering effect would constitute a minor magnitude of impact on the superficial glacial till deposits (including areas classified as Secondary A and Secondary Undifferentiated aquifer), resulting in a potential significance of effect of slight. At aquifer level, the potential magnitude of impact on the Secondary A bedrock aquifers would be negligible, giving a potential significance of effect of neutral.

[23] United Utilities (2013). Marl Hill Tunnel (Sheet 1 of 2) Drawing No. P162/80019125/01/34/2401, Rev. A; United Utilities (2013) Marl Hill Tunnel (Sheet 2 of 2) Drawing No. P162/80019125/01/34/2402, Rev. A.
[24] GEOSLOPE International Ltd, Geostudio (2020) Version 10.2.1.19666.
[25] Domenico & Schwartz (1990) *op. cit.*

255) Regarding surface water receptors, Unnamed Watercourse 403 and Bonstone Brook (between chainage 0 m to 465 m), and Cow Hey Brook and Unnamed Watercourse 426 (between chainage 2560 m to 3765 m), have been identified as potentially being impacted by groundwater drawdown. Based on available information, it is not clear to what degree these watercourses rely on baseflow (derived from groundwater).

256) Bonstone Brook and Unnamed Watercourse 403, located in close proximity to each other, are above the Marl Hill conduit, which is understood to only be around 2 m deep and in superficial deposits where it intersects the watercourses. The shallowness of the conduit would make the likelihood of dewatering effects more likely should the groundwater table be close to the surface, but the drawdown would be limited to a maximum of 2 m in this location. Information from the construction of the existing Haweswater Aqueduct describes the superficial deposits here as ‘Boulder Clay’, suggesting a relatively low permeability. However, the information on the nature of the superficial deposits is very limited and, due to the very shallow depth of the aqueduct, a potential impact on flows cannot be ruled out, particularly during low flow conditions. The potential magnitude of impact is considered to be moderate, giving a potential significance of effect of moderate for both watercourses.

257) Cow Hey Brook is located above a shallower section of the existing aqueduct, which is around 11 m deep and expected to be in superficial deposits where it intersects the watercourse. Information from the construction of the existing Haweswater Aqueduct describes the superficial deposits here as ‘Boulder Clay’, suggesting a relatively low permeability. However, the information on the nature of the superficial deposits is very limited and, due to the shallow depth of the aqueduct, a potential impact on flows cannot be ruled out, particularly during low flow conditions. The potential magnitude of impact is considered to be moderate, giving a potential significance of effect of moderate.

258) The existing aqueduct is located at a depth of approximately 33 m below Unnamed Watercourse 426, and may be either near the top of the bedrock or base of the superficial deposits. Consequently, due to the moderate depth of the aqueduct and likely low permeability nature of the superficial deposits, the potential magnitude of impact is considered to be minor, giving a potential significance of effect of slight.

259) There are no recorded licenced abstractions within the potential zone of influence of the decommissioned aqueduct.

260) PWS4-3 (medium sensitivity), is the only groundwater abstraction expected to exist within range of the existing aqueduct. However, it is located approximately 90 m away from the tunnel, although the exact location and depth of the abstraction borehole is still to be confirmed. Due to the distance and small dewatering rate, the lowering of the water table from groundwater ingress into the existing aqueduct could have a minor long-term magnitude of effect on the supply capacity. Therefore, the potential significance of effect for this PWS would be slight.

261) Impact assessment on GWDTEs from decommissioning phase would come at a later date in a separate report.

<u>Groundwater Quality</u>

262) No impact would be expected on groundwater quality during this phase of Proposed marl Hill Section.

Summary of Effects

263) A summary of the decommissioning phase effects is shown in Table 7.28.

Table 7.28: Summary of Decommissioning Phase Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
Bashall Brook (W556)	High	Changes to flow and sediment transportation regimes	Long term	Major	Large– Significant
Surface Water Quality					
Bashall Brook (W556)	High	Exceedance of water quality standards	Long term	Moderate	Moderate– Significant
Groundwater					
Superficial aquifer – glacial till (diamicton)	Medium	Reduction in aquifer capacity due to lowering of the water table	Long term	Minor	Slight
Secondary A bedrock aquifers (Kirkby Moor Formation & Bannisdale Formation)	High	Reduction in aquifer capacity due to lowering of the water table	Long term	Negligible	Neutral
PWS4-3 (borehole)	Medium	Reduced supply capacity due to the lowering of the water table	Long term	Minor	Slight
Bonstone Brook (W498)	High	Reduced baseflow (dewatering)	Long term	Moderate	Moderate– Significant
Unnamed Watercourse 426 (W516)	High			Minor	Slight
Cow Hey Brook (W535) and Unnamed Watercourse 403 (W484)	Medium			Moderate	Moderate– Significant

7.7 Essential Mitigation and Residual Effects

264) Mitigation is most effective if considered as an integral part of the Proposed Marl Hill Section design to avoid, reduce or offset any adverse effects on the water environment or wider environment. Maintenance and operation of the Proposed Marl Hill Section would be in accordance with environmental legislation and good practice. Procedures similar to those outlined in the CCoP (Appendix 3.2) would be established for all high-risk activities and employees would be trained in responding to such incidents.

265) Embedded mitigation has been included within the assessment outlined in Section 7.6, including the CCoP. The following outlines additional mitigation required to reduce the potentially significant effects identified within the assessment.

7.7.1 Fluvial Geomorphology

266) To mitigate the impact on Sandy Ford Brook, Unnamed Watercourse 430 and Unnamed Watercourse 463 from the temporary access route to Braddup Compound, the following measures are recommended:

- Augment the bed sediment with coarser material (as required) to counteract the increased input of fine sediment during the enabling and construction phases (**Mitigation Item WE1**)
- Traffic management to prevent vehicles driving close to the edge of the access track, reducing the risk of damage to sediment management assets (i.e. silt fencing) and the introduction of large volumes of fine sediment into the watercourses. For example, a give way system to prevent two vehicles using the track at the same time, allowing vehicles to drive along the centre of the access track (**Mitigation Item WE2**)
- Consider increasing the length of the upgraded culvert to increase distance between the watercourses and sources of fine sediment. This would reduce the risk and amount of fine sediment reaching the watercourse (**Mitigation Item WE3**)
- Place coarse material along the bank toe to stabilise the bank (**Mitigation Item WE4**)
- Use a decomposable geotextile on the banks to allow for vegetation re-establishment along the upper and mid-banks and to aid bank re-stabilisation (**Mitigation Item WE5**)
- Reinstatement work be supervised by a geomorphologist or Ecological Clerk of Works with experience of channel restoration (**Mitigation Item WE6**).

267) The reinstatement measures would also be required on Unnamed Watercourse 433 to reduce the risk of channel incision and instability.

268) Measures would be required on Sandy Ford Brook to mitigate for the impact of the discharge of commissioning flows. Green bank protection would be recommended opposite the outfall and at locations where erosion is already taking place, with scour matting used around the outfall (**Mitigation Item WE7**).

269) For both watercourses likely to be impacted by the commissioning flow (Unnamed Watercourse 402 and Sandy Ford Brook), monitoring would be required (**Mitigation Item WE8**). This would likely consist of monitoring changes in the bed and banks for erosion daily for the duration of the commissioning phase. United Utilities would be notified of any changes and remediation would be sought. Remediation would be delivered in consultation with the landowner(s) and the Environment Agency, and could include additional scour matting and green bank protection at the location of any new erosion observed downstream of the outfalls, as well as channel reinstatement after the commissioning phase under the supervision of a geomorphologist or Ecological Clerk of Works with experience of channel restoration.

270) To mitigate for the impacts anticipated as a result of discharge of groundwater ingress to Bashall Brook it is recommended that geomorphological monitoring of the reach is undertaken to identify any movement in the riffle downstream, and bank erosion (**Mitigation Item WE13**[26]). This would be undertaken on a monthly basis for the first 12 months following commencement of discharge, then on

[26] Following review of the mitigation measures, Mitigation Items WE9-WE12 have been intentionally removed

a six-monthly basis (October and February). Review of the need for monitoring would be carried out after five years in consultation with the Environment Agency.

271) If any changes in the structure of the bed or evidence of bank erosion are identified, remedial action would be discussed with the Environment Agency. Action could take the form of gravel augmentation or installation of green bank protection.

7.7.2 Surface Water Quality

272) As outlined in the fluvial geomorphology section above, monitoring of the commissioning flows on the watercourses which may be potentially impacted would be carried out to ensure no degradation in water quality arising from bank disturbance. Mitigation would include water quality monitoring before, during and after this phase of works, as well as visual monitoring of the watercourse in terms of sediment loading and discolouration. Monitoring would need to be supervised by Environmental Clerk of Works (**Mitigation Item WE14**).

273) During the decommissioning phase it is proposed that groundwater ingress from the existing aqueduct would be discharged via the existing outfall. There is potential for this water to be polluted with a range of potential contaminants related to the natural bedrock geology, and current and historical land uses. To mitigate against the uncertainty in the groundwater quality and potential impacts on Bashall Brook from decommissioning flows on surface water quality, it is recommended that further assessment is undertaken (**Mitigation Item WE15**).

274) A water quality monitoring programme would be implemented to help ensure groundwater ingress discharges from the decommissioned aqueduct pass the required discharge standards. Therefore, the primary main objectives of the monitoring programme are to:

- Provide reassurance that the decommissioning flows entering Bashall Brook are not having a significant adverse impact upon surface water quality
- Understand the long-term chemistry of the groundwater surrounding the aqueduct.

275) It is proposed that a programme of surface water quality monitoring work would be undertaken for a period of 12 months once the decommissioning phase has begun and groundwater ingress flows begin discharging from the existing aqueduct. Table 7.29 outlines the proposed water chemistry parameters to be tested as well as the methodology and sampling frequency of each parameter:

Table 7.29 Proposed Chemical Parameters to be Included During Decommissioning Water Quality Monitoring Programme

Analytical Parameters (Water Analysis)	Proposed Type and Frequency of Analysis
Basic Water Chemistry / Condition Parameters	
Flow (river discharge)	Continuous monitoring via flow meter.
Turbidity	Continuous monitoring via in-situ water quality equipment (e.g. hydrologic sonde).
Total Suspended Solids (TSS)	Monthly sample collected and sent to laboratory for analysis. Timing of sampling could be adjusted to capture a range of flow conditions to better understand link between flow and TSS concentrations.
Temperature	Monthly in-situ monitoring via handheld water quality monitoring meter.
Dissolved Oxygen	
pH	
General Inorganic Parameters	
Nitrate	Monthly sample collected and sent to laboratory for analysis. Timing of sampling could be adjusted to capture a range of flow conditions to better understand link between flow and selected general inorganics parameter concentrations.
Ammonium	
Phosphate	
Sulphate	
Chloride	
(Bicarbonate) Alkalinity	
Heavy Metals / Metalloids	
Iron	Monthly sample collected and sent to laboratory for analysis. Timing of sampling could be adjusted to capture a range of flow conditions to better understand link between flow and selected heavy metal / metalloids parameter concentrations.
Manganese	
Calcium	
Potassium	
Arsenic	
Total PAH	
Total EPA-16 PAHs	Monthly sample collected and sent to laboratory for analysis.
Total Petroleum Hydrocarbons	
TPH1 (C_4- C_{40})	Monthly sample collected and sent to laboratory for analysis.

276) It should be noted all details of the water quality monitoring programme presented are subject to change. The details of the water quality monitoring programme have been initially based on known historic land use and existing surface and ground water quality datasets. However, it is anticipated the programme would be refined throughout the proposed 12-month period of monitoring when more data are collected and changes to the programme would be agreed in conjunction with consultation with the relevant statutory consultees. Examples of possible refinements include:

- Investigating relationship between TSS and turbidity, establishing and understanding the relationship between the two parameters. This could allow incident-reporting thresholds related to the scheme to be better tailored and the potential environmental impacts to be better understood

- Inclusion of hydrocarbon testing initially but this can be phased out or removed completely if these pollutants are absent or consistency recorded below detectable limits
- Inclusion of a range of potential mine water contaminants where historic land uses indicate this is required. These can be phased out depending on their presence and/or if concentrations are consistently recorded below detectable limits.

277) In-situ hydrological equipment is proposed to be installed and used to measure flow / discharge as well as turbidity continuously at an appropriate location prior to discharge. Periodic extractive (monthly) sampling, via both instantaneous in-situ monitoring and laboratory analysis, covering a wider suite of parameters would provide a wider understanding of the water quality of the groundwater ingress discharges. As noted in Table 7.29, the timing of monthly sampling could be adjusted to capture a range of flow conditions to better understand link between flow and concentrations of selected parameters.

278) The monitoring plan would include pre-agreed initial measures and interventions that would be implemented should a deterioration occur against appropriate environmental standards. There would be scope for the thresholds of these environmental standards to change over the course of the monitoring programme, based on the data that are collected. As with the suite of parameters monitored/tested, statutory consultees would be consulted, and agreement sought before any environmental standards are adjusted. Two mitigation options are likely to exist: treating decommissioning flows on site and then discharging; or collecting decommissioned flows before they enter a river so they can be taken off site to be suitably treated and disposed of. Both options are likely to require the siphoning of decommissioning flows into holding tanks and / or ponds and applying a treatment specific to the pollutant of concern.

279) The above outlines the basis of a proposed water quality monitoring programme; however, it should be acknowledged it is anticipated the exact and final details of the programme would be agreed for the purposes of discharging an appropriately worded planning condition..

7.7.3 Groundwater

280) Assessments of the potential significant impacts on groundwater during the enabling, construction, commissioning, operation and decommissioning works phases are provided in Section 7.6. The following potential impacts have been assessed as of moderate or greater significance and mitigation measures would be considered. With the implementation of the mitigation measures outlined below all residual potential impacts would be of **neutral** significance, as summarised in Table 7.32.

Private Water Supplies

281) The following PWS have been identified as at potential risk of impact to flow, water quality or associated infrastructure during enabling and construction phases for PWS4-1, PWS4-4 and PWS4-6 and construction only for PWS4-3. Site visits and landowner site meetings would be required to determine the nature and location of the sources in order to understand whether direct or indirect impacts are likely and to plan monitoring measures where required (**Mitigation Item WE16**). This would include confirmation of any associated pipe networks to check whether there would be any additional impact on the infrastructure.

282) Following the survey, the monitoring requirements would be confirmed (**Mitigation Item WE17**). Should monitoring indicate an impact during the proposed work a temporary replacement water supply would be provided. Should monitoring demonstrate disruption by the proposed work these would be repaired or replaced (**Mitigation Item WE18**).

Watercourses

283) The following watercourses have been identified as being at risk from changes to baseflow during the decommissioning phase:

- Bonstone Brook
- Unnamed Watercourse 403

- Cow Hey Brook.

284) As a result, a Flow Monitoring Strategy would be developed and implemented in consultation with the Environment Agency (**Mitigation Item WE19**). The Flow Monitoring Strategy would determine the nature and duration of flow monitoring at each location. The Flow Monitoring Strategy would also identify, should any detrimental effects be detected, what additional measure could be taken to reduce these impacts.

285) Given the current level of uncertainty, the residual significance of effect could remain moderate or be of **slight** significance and this would be determined by the outcome of the monitoring.

GWDTEs

286) Table 7.30 provides a list of additional standard mitigation measures for reducing the potential significance of effect caused by impacts to groundwater flows and quality at GWDTE sites.

Table 7.30: Summary of Additional Standard Mitigation to Reduce Potentially Significant Effects to GWDTEs

Mitigation	Groundwater Flow / Quality	Benefits Provided
Stagger topsoil stripping activities, i.e. smaller sections at a time rather than the whole compound footprint (**Mitigation Item WE20**)	Groundwater quality	Would limit the concentration of suspended solids and associated solutes entering the aquifer(s) and would reduce peak contaminant concentrations.
Monitor weather forecasts, including rainfall / flood warnings and alerts (**Mitigation Item WE21**)	Groundwater quality	To restrict topsoil stripping and vegetation clearance activities when heavy rainfall is forecast, to further reduce the likelihood of suspended solids entering the groundwater environment.
Monitor suspended solids concentrations in the groundwater monitoring network pre, during and post-construction (**Mitigation Item WE22**)	Groundwater quality	To establish a robust baseline for suspended solids concentrations, against which ongoing concentrations could be monitored during construction to identify 'hotspots' or work areas which would need additional mitigation.
Set trigger levels for suspended solids concentrations (**Mitigation Item WE23**)	Groundwater quality	To identify work areas which may need additional mitigation if suspended solids concentrations exceed a pre-determined threshold value.
Reduce dewatering durations (**Mitigation Item WE24**)	Groundwater flow	To limit the duration of groundwater drawdown at GWDTE sites so that the vegetation has a greater chance of recovery.
Minimise footprint of topsoil stripping and vegetation clearance wherever possible (**Mitigation Item WE25**)	Groundwater quality and flow	There is no mitigation for direct habitat loss due to topsoil stripping so minimising this area would have a direct beneficial impact on reducing the extent of potentially significance effects caused by this activity.

287) In addition, the following specific mitigation measures would also be put in place:

- Topsoil stripping and any activity that would have a direct impact on habitats at Braddup House and Slaidburn Road West would be minimised within the Braddup Compound (**Mitigation Item WE26**)
- During the detailed design phase, the opportunity to move the overflow pipe and connection (associated with the Braddup Compound) further north would be considered. This would avoid the need for excavation and reduce potential dewatering impacts on habitats associated with Braddup House (**Mitigation Item WE27**)

- Opportunities to reduce compaction effects by spreading the load of heavy vehicles and plant along access areas would be considered during the detailed design phase. This would reduce potential impacts to habitats at New Laithe, Whinny Lane East and Slaidburn Road West (**Mitigation Item WE28**)
- Direct impacts on habitats at Slaidburn Road West would be avoided by widening the existing access road to the south (i.e. removing the need for topsoil stripping within the site) (**Mitigation Item WE29**)
- Clay bunds would be used to prevent backfilled open-cut trenches from acting as a groundwater drain within the Braddup Compound. This would mitigate against long-term potential impacts to Braddup House (**Mitigation Item WE30**).

288) These specific mitigation measures are shown on Figure 7.8.

289) Table 7.31 outlines the residual effects associated with the Proposed Marl Hill Section, which were identified as potentially significant in Section 7.6, with all mitigation measures in place (i.e. standard and specific). Site-specific GWDTE mitigation measures are shown on Figure 7.8.

Table 7.31 Summary of Residual Effects to GWDTEs

Site Name	Sensitivity	Phase / Effect Type / Mitigation	Highest Residual Magnitude of Impact	Highest Residual Significance of Effect
New Laithe	Medium to low	Enabling / construction phase: intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (Specific mitigation would reduce impacts caused by compaction effects. Standard mitigation would decrease the likelihood of the GWDTE not recovering from flow disturbance caused by topsoil stripping, but there is no specific mitigation possible to avoid direct impacts in the south-west of the site.)	Major	Large – Significant
Braddup House	Low	Enabling phase: intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (Specific mitigation would reduce the footprint of the area affected by direct impacts. Standard mitigation would decrease the likelihood of the GWDTE not recovering from flow disturbance caused by topsoil stripping, but there is no specific mitigation possible to avoid direct impacts at the site.)	Major	Large – Significant
		Construction phase: alterations to flows and levels due to Braddup Compound open-cut connection dewatering. (Standard mitigation would decrease the likelihood of the GWDTE not recovering, but there is no specific mitigation possible to avoid direct impacts in this location.)	Major	Large– Significant
		Construction phase: alterations to flows and levels due to Braddup overflow dewatering. (Mitigation would reduce the impact from major to moderate in the far north of the site, but residual effects with a potential slight	Moderate	Slight

Site Name	Sensitivity	Phase / Effect Type / Mitigation	Highest Residual Magnitude of Impact	Highest Residual Significance of Effect
		significance remain due to the proximity of the works and the sensitivity of the receptor.)		
		Operation phase: intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits. (Mitigation would reduce the impact associated with backfilled open-cut trenches from moderate to minor. Residual effects with a potential neutral significance would be confined to the locations of the permanent below-ground structures.)	Minor	Neutral
Whinny Lane East	Medium to low	Enabling / construction phase: intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (Specific mitigation would reduce impacts caused by compaction effects. Standard mitigation would decrease the likelihood of the GWDTE not recovering from flow disturbance caused by topsoil stripping, but there is no specific mitigation possible to avoid direct impacts in the centre of the site.)	Major	Large – Significant
		Enabling phase: changes to groundwater quality due to ground disturbance associated with the Braddup Compound access area, and leaks and spills of fuels and chemicals. (Mitigation would reduce the likelihood of pollution and the GWDTE not recovering, but a high risk and residual effects with a potential moderate significance remain – confined to the centre of the site, due to the sensitivity of the receptor and direct nature of the works footprint.)	Moderate	Moderate– Significant
Slaidburn Road West	Medium to low	Enabling / construction phase: intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (Mitigation would reduce the impact from major to minor in the far south of the site, but residual effects with a potential slight or neutral significance remain due to the proximity of the works and the sensitivity of the receptor.)	Minor	Slight
		Enabling phase: changes to groundwater quality due to ground disturbance associated with the Braddup Compound access area, and leaks and spills of fuels and chemicals. (Mitigation would reduce the impact from moderate to minor in the far south of the site, but residual effects with a potential slight or neutral significance remain	Minor	Slight

Site Name	Sensitivity	Phase / Effect Type / Mitigation	Highest Residual Magnitude of Impact	Highest Residual Significance of Effect
		due to the proximity of the works and the sensitivity of the receptor.)		

7.7.4 Summary

290) A summary of mitigation and residual effects are shown in Table 7.32

Table 7.32: Summary of Mitigation and Residual Effects

Receptor	Mitigation	Magnitude (with Mitigation)	Residual Effect and Significance
Fluvial Geomorphology			
Sandy Ford Brook (W530)	12) Augment sediment (**WE1**) 13) Traffic management (**WE2**) 14) Culvert lengthening (**WE3**) 15) Reinstate the natural bed and augment the sediment (**WE4**) 16) Stabilise the bank (**WE5**) 17) Erosion monitoring (**WE8**) 18) Bank protection (**WE7**) 19) Remediation following commissioning flows (as required)	Minor	Slight
Unnamed Watercourse 430 (W520)	20) Augment sediment (**WE1**) 21) Traffic management (**WE2**) 22) Culvert lengthening (**WE3**) 23) Reinstate the natural bed and augment the sediment (**WE4**) 24) Stabilise the bank (**WE5**).	Minor	Slight
Unnamed Watercourse 463 (W557)	25) Augment sediment (**WE1**) 26) Traffic management (**WE2**) 27) Culvert lengthening (**WE3**) 28) Reinstate the natural bed and augment the sediment (**WE4**) 29) Stabilise the bank (**WE5**).	Minor	Slight
Unnamed Watercourse 433 (W523)	30) Augment sediment (**WE1**) 31) Reinstate the natural bed and augment the sediment (**WE4**)	Minor	Slight

Receptor	Mitigation	Magnitude (with Mitigation)	Residual Effect and Significance
	32) Stabilise the bank (**WE5**).		
Bashall Brook (W556)	33) Geomorphological monitoring and adaptive management strategy (**WE13**).	Major	Large– Significant
Unnamed Watercourse 402 (W483)	34) Erosion monitoring (**WE8**) 35) Remediation following commissioning flows (as required)	Minor	Slight
Surface Water Quality			
Bashall Brook (W556)	36) Environmental Clerk of Works and specialist oversight to monitor commissioning flows ensuring applicable water quality standards within discharge watercourse receptors are maintained (**WE14**)	Minor	Slight
	37) Water quality monitoring plan for decommissioning flows (**WE15**).	Moderate	Moderate– Significant
Groundwater			
PWS4-1, PWS4-3, PWS4-4 and PWS4-6	38) Site visit and landowner meeting to confirm location and nature of source and associated infrastructure (**WE16**) 39) Monitoring of flow and quality during the proposed work (**WE17**) 40) Replacement water supply (temporary or permanent) if indicated by monitoring. Repair or replacement of associated infrastructure if required (**WE18**).	Negligible	Neutral
Bonstone Brook (W498) Cow Hey Brook (W535) Unnamed Watercourse 403 (W484)	41) Monitoring Strategy would be developed and implemented in consultation with the Environment Agency. The Monitoring Strategy would determine the nature and duration of monitoring at each location. The Monitoring Strategy would also identify, should any detrimental effects be detected,	Moderate to minor	Moderate to slight

Receptor	Mitigation	Magnitude (with Mitigation)	Residual Effect and Significance
	what additional measure could be taken to reduce these impacts (**WE19**).		
New Laithe	42) Standard best practice mitigation measures set out in Table 7.30 to increase the likelihood of recovery of the GWDTE (**WE20 – WE25**) 43) Spreading the load of heavy vehicles and plant to reduce compaction effects associated with the Bonstone Compound access area (**WE28**).	Major	Large– Significant
Braddup House	44) Standard best practice mitigation measures set out in Table 7.30 to increase the likelihood of recovery of the GWDTE (**WE20 – WE25**) 45) Minimise topsoil stripping in the Braddup Compound, and any activity that would have a direct impact on habitats within Braddup House (**WE26**) 46) Moving the overflow pipe and connection (associated with the Braddup Compound) further north, to avoid the need for excavation and reduce potential dewatering impacts (**WE27**) 47) Use of clay bunds to prevent backfilled open-cut trenches from acting as a groundwater drain within the Braddup Compound (**WE30**).	Major	Large– Significant
Whinny Lane East	48) Standard best practice mitigation measures set out in Table 7.30 to increase the likelihood of recovery of the GWDTE (**WE20 – WE25**) 49) Spreading the load of heavy vehicles and plant to reduce compaction effects associated with the Braddup Compound access area (**WE28**).	Major	Large– Significant
Slaidburn Road West	50) Standard best practice mitigation measures set out in Table 7.30 to increase the likelihood of recovery of the GWDTE (**WE20 – WE25**)	Minor	Slight

Receptor	Mitigation	Magnitude (with Mitigation)	Residual Effect and Significance
	51) Widening the existing access road to the south to avoid topsoil stripping in the Braddup Compound access area, and any activity that would have a direct impact on habitats within Slaidburn Road West (**WE29**).		

7.8 Cumulative Effects

291) The following section provides an overview of the potential cumulative effects from different proposed developments and land allocations, in combination with the Proposed Marl Hill Section (i.e. inter-project cumulative assessment). Data on proposed third party developments and land allocations contained in development plan documents were obtained from various sources, including local planning authority websites, online searches, and consultations with planning officers. Proposed development data were then reviewed with a view to identifying schemes or land allocations whose nature, scale and scope could potentially give rise to significant environmental effects when considered in combination with the likely effects arising from the Proposed Marl Hill Section.

292) Intra-project cumulative impacts i.e. two or more types of impact acting in combination on a given environmental receptor, property or community resource are considered in Chapter 14: Communities and Health.

293) The over-arching cumulative effects of the Proposed Programme of Works, i.e. the five proposed replacement tunnel sections in combination, are considered in Volume 2 Chapter 19: Cumulative Effects. In addition Volume 2 Chapter 19 examines the cumulative effects associated with the outcomes from Volume 2 (delivery and operation of the main construction compounds, tunnel and construction traffic routes).

294) Based on professional judgement, it was concluded that there is potential for environmental effects associated with the Proposed Marl Hill Section to act cumulatively with proposed developments within a 5 km radius (see Table 7.33). The remainder of this section describes the outcome of this cumulative assessment in terms of the additional and combined effects.

295) None of the developments identified within 5 km of the Proposed Marl Hill Section are likely to cause a cumulative effect on any watercourses identified in the fluvial geomorphology or surface water quality baselines.

Table 7.33: Summary of Cumulative Effects

Proposed Development	Nature / Scope of Effects	Commentary on Cumulative Effects
Use of Waddington Fell Quarry as part of the project materials and waste strategy	Excavated materials would be disposed of at Waddington Fell Quarry as part of a Restoration Plan for the quarry	There is no plan to impact on existing excavations or groundwater levels. The proposal would need to be supported, as required, by a groundwater risk assessment to obtain the appropriate Environmental Permit. As a result, no cumulative impact is expected on groundwater.
Variation of condition to extend mining operations at Bankfield Quarry, Clitheroe until 2033 (Application Ref. LCC/2018/0060 – Application Pending Decision)	This development is an extension of duration of working an existing limestone quarry (operated by Tarmac Aggregates Ltd), but with no change to the areal extent or depth of working. It is located approximately 4 km east-south-east of the Braddup Compound and is considered unlikely to cause any further cumulative impact.	The current planning permission (Ref. 3/97/636) allows working to a depth of 50 mAOD, subject to conditions controlling the development and environmental protection measures. Post-working restored water level would be 65.35 mAOD. These levels are approximately 100 m below and likely down groundwater gradient from the Braddup Compound. The Environmental Statement submitted with application

Proposed Development	Nature / Scope of Effects	Commentary on Cumulative Effects
		LCC/2018/0060[27] states that *'The deeper regional groundwater system is associated with the Carboniferous Limestone. This system operates in discrete blocks depending on the specific limestone formation and faulting. The Horrocksford Hall Thrust fault located on the northern boundary of the quarry forms a hydraulic barrier between the quarry and the River Ribble.* Distance and the intervening valley of the River Ribble separate it from the Proposed Marl Hill Section.

7.8.1 Off-Site Highways Works

296) The impact on geomorphology and surface water quality from off-site highways works has been assessed. This is reported in Volume 5. The impacts on groundwater from the off-site highways works have not been presented in Volume 5 but will be presented under separate cover.

297) For geomorphology there would likely be an effect to Bonstone Brook from increased fine sediment input and disturbance to the bed and bank during construction. This would lead to minor impact with a moderate significance of effect. To mitigate this, coarse sediment should be added to the channel where impacts occur. This would result in a residual impact of minor with a slight significance of effect i.e. not significant in the context of the EIA Regulations.

298) In addition, there would likely be an effect to Unnamed Watercourse 2096 due to potential channel instability. This would lead to moderate impact with a moderate significance of effect. To mitigate this, coarse sediment should be added to the channel where impacts occur. This would result in a residual impact of minor with a slight significance of effect.

299) For surface water quality, there would likely be no significant effects as a result of the off-site highways works.

7.8.2 Proposed Ribble Crossing

300) The impact on water environment for the Proposed Ribble crossing has been assessed. This is reported in Volume 6 but there follows a short summary of environmental effects.

301) For geomorphology there would likely be an impact on the River Ribble, Coplow Brook and Greg Sike due to increased fine sediment, disturbance to bed and banks during construction. In addition, there would be an impact on the River Ribble due to loss of riparian vegetation. The impacts on the River Ribble would have a minor magnitude with a moderate significance of effect prior to mitigation– a significant effect in the context of the EIA Regulations. For Coplow Brook and Greg Sike the impacts would likely be moderate with a moderate significance of effect prior to mitigation, also significant in the context of the EIA Regulations. These effects would be mitigated by reinstating natural bed features and using a biodegradable geotextile on the banks to allow for vegetation re-establishment. This would result in a residual effect of negligible with a neutral significance of effect.

[27] Tarmac Aggregates Limited (2018) Bankfield Quarry, Lancashire - Planning Application for An Extension of Time Bankfield Quarry by Variation of Planning Condition - Environmental Statement. November 2018.

302) The surface water quality impact assessment did not identify any significant effects.

303) For ground there could be the creation of vertical pathway for surface contamination to migrate because of piling within bedrock and alluvial aquifers. This would likely have a moderate impact with a moderate significance of effect, and therefore significant in the context of the EIA Regulations. To mitigate the impact a piling risk assessment would be carried out to assess these potential impacts and identify mitigation measures (if required) during detailed design of the Proposed Ribble Crossing. This would result in a residual impact of negligible with a neutral significance of effect.

7.9 Conclusion

304) This chapter of the Environmental Statement has considered the potential water environment impacts associated with the enabling, construction, commissioning, operation and decommissioning works along the route of the Proposed Marl Hill Section. This has included an assessment of the impacts on fluvial geomorphology, surface water quality and groundwater.

305) The assessment has shown that some impacts can be lessened through good practice mitigation detailed in the Construction Code of Practice (CCoP). Other impacts require specific mitigation.

306) For fluvial geomorphology, mitigation would be required for the impact of the temporary access route to Braddup Compound on Sandy Ford Brook, Unnamed Watercourse 430 and Unnamed Watercourse 463. This could be delivered through sediment augmentation, traffic management, lengthening of the culverts, and reinstating the natural bed and stabilising the banks post-construction. The reinstatement measures would also be required on Unnamed Watercourse 433 to mitigate impacts associated with temporary culvert crossings.

307) Green bank protection would be recommended on Sandy Ford Brook to mitigate the impact of the discharge of commissioning flows. Monitoring would also be recommended on Unnamed Watercourse 402 and Sandy Ford Brook to mitigate the impact of the discharge of commissioning flows. If any changes in the structure of the bed or evidence of bank erosion are identified, action could take the form of additional scour matting and green bank protection, as well as channel reinstatement.

308) To mitigate the impact of the decommissioning flows on Bashall Brook, geomorphological monitoring and an adaptive management strategy would be recommended.

309) To ensure applicable surface water quality standards within Bashall Brook are maintained during the commissioning phase, flows would be monitored by an Environmental Clerk of Works. In addition, a water quality monitoring plan would be carried out for decommissioning flows entering Bashall Brook.

310) For PWS4-1, PWS4-3, PWS4-4 and PWS4-6, site visits and landowner meetings would be convened to confirm the location and the nature of the source of the PWS and any associated infrastructure. The site visits would also determine the requirements for monitoring of groundwater flow and quality and the requirements for replacing the water supply during the works.

311) Several watercourses have been identified as being at risk from changes to baseflow during the decommissioning phase (Bonstone Brook, Cow Hey Brook and Unnamed Watercourse 403). Monitoring of these receptors would therefore take place.

312) Standard and site-specific mitigation measures have been proposed to reduce impacts on GWDTEs, however, in some instances, direct impacts could not be avoided.

313) For surface water quality, PWS and the dewatering impacts on the aquifers, the mitigation measures reduce the significance of effect to slight or lower. There could be residual impacts of moderate to slight on Bonstone Brook, Cow Hey Brook and Unnamed Watercourse 403, and large to moderate residual impacts on some GWDTEs.

314) A residual significant effect would remain for decommissioning flows potentially impacting on water quality. This is due to the unknown nature of any ingress waters, though the monitoring of water quality may provide a better understanding of any impacts, at which point the significance of effect could be reappraised.

315) For fluvial geomorphology, the mitigation measures reduce the significance of effect to slight or lower for most impacts, which is not significant. The impact of groundwater ingress being discharged during decommissioning on the fluvial geomorphology of Bashall Brook would likely have a significant residual effect.

316) Surplus materials from the Proposed Marl Hill Section would be directed to Waddington Fell Quarry, which is currently the subject of a separate planning application relating to the acceptance of inert tunnel arisings from HARP. There are no anticipated cumulative effects on fluvial geomorphology, surface water quality or groundwater when taking account of the proposed Waddington Fell Quarry development.

7.10 Glossary and Key Terms

317) Key phrases and terms used within this technical chapter relating to Water Environment are defined within Appendix 1.2: Glossary and Key Terms.