Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

Environmental Statement

Volume 2

Chapter 7: Water Environment

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Water for the North West

Haweswater Aqueduct Resilience Programme - Proposed Bowland 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 Bowland 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 potential sources of 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 Bowland Section. Mitigation measures have been proposed to avoid, reduce or offset any potential effects and these embedded mitigation measures have been taken into account 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 Proformas
- Appendix 7.4: Water Quality Baseline Information
- Appendix 7.5: Long section extracts from Martin Preene Report
- Appendix 7.6: Earthworks Dewatering and Groundwater Excavation and Flow Disruption
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- Figure 7.7: Groundwater Dependent Terrestrial Ecosystems – Location Plan
- Figure 7.8: Groundwater Dependent Terrestrial Ecosystems – Site-Specific Mitigation Measures.

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 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 effects considered either within this chapter, or within Chapter 8: Flood Risk.

[1] Jacobs (2019) *Haweswater Aqueduct Resilience Programme Proposed Bowland 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 February 2021)	2021 Environmental Statement
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 Bowland 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 pipes and would result in new constant discharges to surface waters.	**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.
	Decommissioning works could lead to a change in local runoff and infiltration	**Scoped in** – this cannot be determined until the method of decommissioning is known.	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 February 2021)	2021 Environmental Statement
	patterns and rates, leading to changes in stream flow.		
Surface water quality (construction)	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.
	Degradation of surface water dependent habitats.	Not referred to in Scoping Report.	**Scoped in** – surface water habitats that potentially interact with enabling and construction activities. **Scoped out** – surface water 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 would most likely be discharged via pipes to surface watercourses and may impact upon surface water quality in receiving watercourses.	**Scoped in** - an extensive ground investigation (GI) is programmed for the Proposed Bowland Section which would include water quality testing of the 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.	**Scoped in** – however, assessed under decommissioning as potential ingress from the abandoned sections has been considered separately in the assessment from the operation of the new asset.
Surface water quality (commissioning)	The quality and quantity of water discharge from the existing aqueduct to surface water features during commissioning phase.	Not referred to in Scoping Report.	**Scoped in** – for watercourses receiving discharges from commissioning flows.
Surface water quality (decommissioning)	The quality and quantity of continued / long-term water discharge from the existing aqueduct to surface water features.	Not referred to in Scoping Report.	**Scoped in** – for watercourses receiving discharges from decommissioning flows.

Receptor	Matter / Potential Effect	Conclusion in the Scoping Report (October 2019) and Scoping Addendum February 2021)	2021 Environmental Statement
Groundwater (construction)	Changes to groundwater quality due to the use of cementitious materials.	**Scoped out** except where the Proposed Bowland Section interacts with sensitive fractured aquifers.	**Scoped out –** due to limited use of wet concrete and cementitious grout during shaft construction and tunnelling.
	Temporary tunnel dewatering.	**Scoped in**.	**Scoped out –** due to the use of a deep tunnel.
	Potential recharge of abstracted groundwater from dewatering could also cause the groundwater level to rise.	**Scoped in**.	**Scoped out –** as no recharge to the ground is proposed as part of the design.
Groundwater (operation)	Watertight new aqueduct may result in groundwater rebound.	**Scoped in**.	**Scoped out –** as the decommissioning strategy would not permanently fill the aqueduct with grout or cement (i.e. would permanently fill or seal it).
Groundwater (decommissioning)	The aqueduct is permanently filled with grout or cement.	**Scoped out** except for where sensitive groundwater environment attributes are located, or in areas with existing groundwater flooding issues.	**Scoped out –** for all receptors as this is no longer applicable.

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 and guidance.

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.
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 respect of 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 major, moderate, minor, or negligible

  - The significance of effect using the scale very large, large, moderate, slight or neutral. For significant effects (moderate or greater), 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 has taken 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 (taking into account 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 the scheduled GI. This characterises the groundwater environment intercepted by the Proposed Bowland 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 have considered the wider attributes and potential impacts on groundwater abstractions (licensed and unlicensed), Groundwater Dependent Terrestrial Ecosystems (GWDTEs) and baseflow contributions to surface waters. The GI supports the assessment of potential groundwater flow disturbances as a result of the proposed decommissioning strategy.

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 Bowland 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 and Northern Ireland Forum for Environmental Research (SNIFFER) WFD95 Wetland Typology methodology[6] has then 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

[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.

Conceptual Site 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 then been derived by considering both the ecological designation of the site, and the degree of groundwater dependency of each GWDTE. The impact assessment has then been determined using the CSM to project anticipated impact(s) on groundwater flows, levels and quality at the site, as a result of a given works item.

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) should 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 is provided which supports the reporting of a single significance category. This considers 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 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 BBAP 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 Bowland Section area. 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 the Proposed Bowland 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

		Magnitude of Impact			
		Negligible	Minor	Moderate	Major
Sensitivity	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 in-situ groundwater quality data were available at the time of writing
- Draft unchecked GI datasets only were available at the time of writing. The assessment is reliant on the accuracy of the draft information reported by the GI contractor at this stage
- The draft unchecked GI dataset has been used for this assessment. In areas where no data were available, the nearest geological and hydrogeological information was extrapolated from the wider available dataset
- The identification of potentially contaminated land relies on information discussed in Chapter 11: Soils, Geology & Land Quality
- It has been assumed that bedrock would not be excavated to construct the attenuation ponds
- Information relating to private water supplies (PWS) is based on data provided by United Utilities through consultation with landowners (initial consultation relating to proposed GIs 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-level information specific to individual GWDTE sites is limited; however, where possible, data have been extrapolated using the draft unchecked GI datasets and associated groundwater-level monitoring information
- Hydrogeological surveys were not undertaken at all potential GWDTE sites; however, where survey data are 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 overarching 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 over time and have been forecast by United Utilities 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
- At the time of writing the following vertical design assumptions would apply:
  - Trenches would be 5 m deep and 5 m wide for single connection and 50 m wide for multi-line connections
  - No excavation would be required for access roads and compound areas, except for the portal at Newton-in-Bowland and access roads and working platform associated with the Lower Houses Compound shaft, where excavations would be required. The dewatering impacts associated with excavations for the portal and associated with the Lower Houses Compound are discussed in the impact assessment
  - 2 m deep excavation would be required for drainage ponds
  - All topsoil strip areas would be excavated 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 the Proposed Bowland Section 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 Bowland Section.
Surface water quality	500 m	Defined as an area around the above-ground activities related to Proposed Bowland Section (e.g. construction areas, site compounds, construction laydown areas and haul routes).
Groundwater	1 km	In all directions around the Proposed Bowland 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 Bowland 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, drainage 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. A GI data package has also been used within the assessment.

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)
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)
BGS geological information	The Millstone Grit of Northern England (Technical Report: CR/05/015N)

Data Source	Reference
	BGS Technical Report: 22. The Carboniferous Limestone of Northern England CR/05/076N
National Biodiversity Network Atlas (NBN)	https://nbnatlas.org/about-nbn-atlas/ (Accessed January to July 2020)
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)
Draft unchecked GI data package (borehole logs, packer tests, groundwater-level information)	Preliminary GI data received by end of April 2020 (data freeze)
Geophysics shallow section report	Fugro Geoservices Limited (2020a) T03 Shallow Geophysical Survey Interpretive Report. Haweswater Aqueduct Resilience Programme (HARP). Fugro document number: D19020-T03-S-INT 01. For United Utilities Limited
Geophysics deep section report	Fugro Geoservices Limited (2020b) Haweswater Aqueduct Resilience Programme (HARP). Deep Seismic Investigation. T03 Report. Fugro document number: D19020-T03-D-INT 02. For United Utilities Limited
Haweswater Aqueduct hydrogeological desk study	Preene Groundwater Consulting Limited. 2014. Haweswater Aqueduct Hydrogeological Desk Study Interim Report. Reference: 14-142.102.V1
Cross-sections made available by United Utilities used to determine the depth of existing infrastructure	Consultation

Site Work

27) A fluvial geomorphology site walkover was undertaken on 7 February 2018 for the River Hodder and between 3 and 4 December 2020 and on 21 April 2020 for all other watercourses. The site walkovers included all watercourses that potentially could be impacted by the Proposed Bowland 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 16 and 17 March 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.

31) As previously indicated, a phase of GI is ongoing at the time of writing. Draft unchecked data available at the time of writing have been used in the assessment.

7.5.2 Baseline Overview

Fluvial Geomorphology

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

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

34) There is one very high, three medium, and three low watercourses carried forward for further assessment in the Proposed Bowland 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	Watercourse Name	Description	Project Interaction(s)
Very High	Very high	River Hindburn (W478)	A meandering channel with a range of geomorphological processes and features. Point, lateral and medial bars, berms, riffles, bars, 35 m of bank erosion, and large woody debris were all observed. No modifications were seen on this watercourse, giving it a sensitivity of very high.	Downstream of watercourses which would be crossed by construction access route (Unnamed Watercourse 169) and receive site drainage (Cod Gill); therefore, potential impact pathway.
Medium	Medium	River Hodder (W477)	A meandering channel with a range of geomorphological processes and features. Berms, riffles, medial bars and side bars and 550 m of bank erosion were all observed. Modifications noted within the study reach included weirs, footbridges, road bridges, a pipe bridge for the Haweswater Aqueduct and 115 m of bank reinforcement. The channel appeared to be in natural equilibrium, but due to the extent of the modifications a medium sensitivity has been assigned.	Crossed by construction access route. Receiving discharge from access route (surface runoff during construction), as well as commissioning flows and groundwater ingress (during operation). Surplus material storage.
Not in Scoping Report	Medium	Cod Gill (W206)	Within the surveyed reach this watercourse was seen to be a straightened channel with no significant geomorphological processes or features evident. Downstream of the surveyed reach, there is 250 m of sinuous channel. Desk-based observations suggest this could be a more natural reach, with some evidence of bank erosion seen. This could indicate the presence of geomorphological features such as berms or bars. There are at least two culverts downstream of this point. Although desk-based observations suggest there are some natural processes, the presence of modifications along the reach gives this watercourse a medium value.	Receiving discharge from site compound drainage and from commissioning flows.
Not in Scoping Report	Medium	Unnamed Watercourse 385 (W462)	A sinuous channel with evidence of some natural features and processes observed such as berms and 3 m of bank erosion. Some variation in bed substrate (silt, fine and coarse gravels) observed. No modifications were noted within the study reach; therefore, a medium value has been assigned.	Crossed by construction access route. Dewatering impacts.
Not in Scoping Report	Low	Unnamed Watercourse 169 (W215)	This is a straightened channel with no significant geomorphological processes or features evident. Therefore, a sensitivity of low has been assigned.	Crossed by construction access route.

Sensitivity from Scoping Report	Revised Sensitivity	Watercourse Name	Description	Project Interaction(s)
Not in Scoping Report	Low	Unnamed Watercourse 384 (W461)	A sinuous channel with no significant geomorphological processes or features evident. Modifications noted within the study reach include a culvert, land drainage outfalls, bank reinforcement and a trash screen. The presence of few geomorphological features and extent of modification give this watercourse a low sensitivity.	Crossed by construction access route. Receiving discharge from site compound. Surplus material storage.
Not in Scoping Report	Low	Unnamed Watercourse 386 (W463)	Based on desk-based observations this watercourse appears to be a sinuous channel with few geomorphological processes or features. No obvious modifications were observed. Therefore, a low sensitivity has been assigned.	Crossed by construction access route. Receiving discharge from site compound. Surplus material storage.

Surface Water Quality

35) Two surface water WFD water bodies and associated catchments have been identified that interact with the Proposed Bowland 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 Bowland Section interacts refer to Appendix 7.4.

Table 7.9: Baseline WFD Classifications

Element	River Hindburn	Hodder – conf Easington Bk to conf Ribble
Water body ID	GB1120766050	GB112071065560
Catchment size	49.1 km^2	69.3 km^2
Hydromorphological designation	Not designated artificial or heavily modified	Not designated artificial or heavily modified
Overall status	Moderate	Moderate
Ecological status	Moderate	Good
Physico-chemical quality elements	High	High
Chemical status	Fail	Fail
Designated Site (SSSI / SAC / SPA)	Bowland Fells SSSI, Far Holme Meadow SSSI and Bowland Fells SPA	Bowland Fells SSSI and Bowland Fells SPA
Surface water abstractions	No	No
Surface water dependent habitats	No	Yes
Atlantic salmon	Yes	Yes
High-priority surface water nitrate issue area	No	No
High-priority sediment issue area	Yes	Yes
High-priority surface water pesticide issue area	No	No
High-priority faecal indicator organisms issue area	Yes	Yes
Phosphates issue area – high priority	No	No
Project interaction	Proposed access routes, site compounds, construction laydown areas and other above-ground activities associated with the Proposed Bowland Section are located within the River Hindburn catchment, including associated tributaries. However, construction	Proposed access routes, site compounds, construction laydown areas and other above-ground activities associated with the Proposed Bowland Section are located within the River Hodder catchment, including associated tributaries.

Element	River Hindburn	Hodder – conf Easington Bk to conf Ribble
	activities would not lie within 500 m of the River Hindburn itself.	

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

River Hindburn

37) The River Hindburn is an Environment Agency Main River and holds an overall moderate status but a high status for physico-chemical quality elements under WFD. Land use within the catchment is 100 % rural, with isolated farmsteads, residential holdings, fields, and forested areas with local main and minor roads connecting the catchment area to the surrounding major road networks.

38) The catchment encompasses part of Bowland Fells SSSI and SPA in middle to southern reaches, the Far Holm Meadow SSSI within its middle to northern reaches, and part of the Robert Moor SSSI within the northern reaches. However, in relation to the Proposed Bowland Section these areas are located above deep sections of the proposed aqueduct only (see Appendix 7.4 for further details). The River Hindburn is recognised as a watercourse containing habitat for spawning and migrating Atlantic salmon which is a protected species. No surface water dependent habitats or surface water abstractions have been identified in the River Hindburn catchment within the assessment area associated with the Proposed Bowland Section.

39) There are a number of Unnamed Watercourse which could potentially interact with the Proposed Bowland Section which are located within the River Hindburn catchment documented in Table 7.10 and shown on Figure 7.3. These Unnamed Watercourse are either tributaries of the River Hindburn or are other water features, such as drainage channels or ditches.

Table 7.10: Surface Water Features Identified within 500 m of Proposed Bowland Section

WFD Catchment	Unnamed Water Feature	Project Interaction
River Hindburn	▪ Cod Gill (W206) ▪ Unnamed Watercourse 163 (W207) ▪ Unnamed Watercourse 169 (W215) ▪ River Hindburn (W478)	Within 500 m of Lower Houses Compound and / or haul route and located within the drainage catchment of above-ground activities.

Hodder – Conf Easington Bk to Conf Ribble

40) The Hodder – conf Easington Bk to conf Ribble WFD surface water body forms part of the River Hodder, which is an Environment Agency Main River. The WFD surface water body holds an overall moderate status and this stretch of the River Hodder holds a high status for physico-chemical quality elements, under WFD. 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.

41) The western-most point of the catchment encompasses part of Bowland Fells SSSI and SPA. However, none of these designated sites occur within the assessment area and only cover the section encompassed

by the tunnel. Two surface water habitats have been identified within the assessment area. These habitats consist of an area of Lowland Fen (National Grid Reference (NGR) SD 68696 50425) and an area of Purple Moor Grass and Rush Pasture (NGR SD 69238 50344). The area of Lowland Fen is identified at the same location as the GWDTE identified as Gamble Hole Farm Pasture. Further details are provided on these habitats in Appendix 7.4 and for the Gamble Hole Farm Pasture GWTDE, further information is provided in Appendix 7.2.

42) One surface water abstraction, a spring near Lower Underhand Farm, near NGR SD 705 482, has been identified within the Hodder – conf Easington Bk to conf Ribble catchment. This spring is noted as being for general farming and domestic purposes (see Appendix 7.4 for further details). No surface water abstractions have been identified within the assessment area.

43) There are a number of Unnamed Watercourse which could potentially interact with the Proposed Bowland Section which are located within the Hodder – conf Easington Bk to conf Ribble catchment documented in Table 7.11 and shown on Figure 7.3. These Unnamed Watercourse are either tributaries of the Hodder – conf Easington Bk to conf Ribble WFD surface water body or are other water features, such as drainage channels or ditches.

Table 7.11: Surface Water Features Identified within 500 m of Proposed Bowland Section

WFD Catchment	Unnamed Water Feature	Project Interaction
Hodder - conf Easington Bk to conf Ribble	▪ Heaning Brook (W460) ▪ Unnamed Watercourse 384 (W461) ▪ Unnamed Watercourse 385 (W462) ▪ Unnamed Watercourse 386 (W463) ▪ River Hodder (W477) ▪ Unnamed Watercourse 1312 (W1382)	Within 500 m of Newton-in-Bowland Compound and / or haul route and located within the drainage catchment of above-ground activities.

Groundwater

44) The Proposed Bowland Section tunnel is centred about 175 m above Ordnance datum (AOD) which equates to a maximum depth of 11 metres below ground level (mbgl) at the shaft locations. Elsewhere, the maximum depth to the tunnel is expected to be significantly higher and up to a maximum of 285 mbgl, as generally ground level is higher in the central part of the Proposed Bowland Section.

45) Details of bedrock and superficial aquifers from desk-study information are presented in Table 7.12 and Table 7.13. They include descriptions of the lithology of each geological unit present, the aquifer designations of 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 assessment, the bedrock stratigraphic units are discussed at formation level only.

Table 7.12: Bedrock Aquifer Information

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
Millstone Grit Group	Fine to very coarse-grained sandstones, interbedded with siltstones and mudstones, with subordinate shaley mudstone, claystone, coals and seat earths	Secondary A	Forms an important local aquifer that provides water for both potable and industrial use. Multi-layered aquifer, in which thick, massive sandstone horizons form discrete aquifers, separated by mudstones and shales (perched water tables). Mainly fracture flow, as the sandstones are well cemented, with low porosity. Flow in the aquifer tends to	Crossed by the Proposed Bowland Section

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
			decrease rapidly with depth. Artesian conditions occur in places, and there are abundant springs located at the base of the sandstone layers, and at junctions between the shale and sandstone horizons, some of which are used for public supply.	
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 Bowland Section
Chatburn Limestone Formation	Well-bedded packstone limestones, with chert lenses and subordinate thin beds of shaley mudstone and siltstone	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 a 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[10] due to extensive faulting. This forms an important local aquifer (multi-layered), providing water for potable and industrial use. Where boreholes have been tested in this formation, yields range from 240 m^3/day to 1,920 m^3/day.[11]	Crossed by the Proposed Bowland Section
Clitheroe Limestone Formation	Packstones, wackestones and subordinate grainstones and mudstones with reef limestones	Secondary A	Similar hydrogeological characteristics to the Chatburn Limestone Formation.	Crossed by the Proposed Bowland Section
Pendleside Limestone Formation	Fine to coarse-grained, bioclastic, commonly graded, cherty packstones,	Secondary A	Similar hydrogeological characteristics to the Chatburn Limestone Formation.	Crossed by the Proposed

[10] Envireau Water (2012) *Lanehead Quarry Hydrogeological Impact Assessment*.
[11] BGS (2005) *Baseline Report Series: 22. The Carboniferous Limestone of Northern England*.

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
	interbedded with wackestone, sporadic limestone conglomerate, and mudstone in the lower part			Bowland Section
Hodderense Limestone Formation	Wackestones, with micritic nodules, sporadic interbedded packstones and common mudstones	Secondary A	Similar hydrogeological characteristics to the Chatburn Limestone Formation.	Crossed by the Proposed Bowland Section
Bowland Shale Formation	Mainly fissile and blocky mudstone, with subordinate sequences of interbedded limestone and sandstone	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 Bowland Section

Table 7.13: 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 Bowland Section
Head	Comprises sand and gravel, locally with lenses of silt, clay or peat and organic material	Secondary Undifferentiated	Typically mixed flow with varying permeability. The extent and thickness of these deposits limits the available groundwater yield contained within the more productive sand and gravel horizons and groundwater abstraction is therefore unlikely. The unit may contain multiple perched water tables above discontinuous clay / peat lenses.	Crossed by the Proposed Bowland Section

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
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 the dominance of clay in this unit may limit its potential as an aquifer.	Crossed by the Proposed Bowland Section
Alluvial fan deposits	Alluvium, with a low-angle cone form	Secondary A	Typically intergranular flow with high permeability. Similar hydrogeological characteristics to alluvium.	Lies within the wider groundwater assessment area
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 decomposition and soil compression and often reduces with depth.	Crossed by the Proposed Bowland Section
River terrace deposits	Sand and gravel, locally with lenses of silt, clay or peat	Secondary A	Typically intergranular flow with high permeability. Sand and gravel deposits would typically comprise high porosity and high permeability and can locally yield significant groundwater volumes, if clay lenses are infrequent and sand / gravel deposits are of sufficient thickness. Local groundwater abstraction possible.	Crossed by the Proposed Bowland Section
Talus	Clast-supported accumulation of angular rock fragments	Secondary A	Typically intergranular flow with high permeability. The extent and thickness of these deposits limits the available groundwater yield, and groundwater abstraction is therefore unlikely.	Lies within the wider groundwater assessment area
Glaciofluvial sheet deposits	Sand and gravel, locally with lenses of silt, clay or organic material	Secondary A	Typically intergranular flow with high permeability. Sand and gravel constituents may locally yield significant groundwater volumes where deposits are of sufficient thickness. The aquifer may contain perched water	Lies within the wider groundwater assessment area

Hydrogeological Unit	Description	Aquifer Designation	Hydrogeology	Relation to Route Proposal
			tables above discontinuous clay lenses. Local groundwater abstraction possible.	

46) Table 7.12 and Table 7.13 also describe the location of the Proposed Bowland Section in relation to the bedrock formations and superficial deposits present, 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.

47) Groundwater vulnerability across the groundwater assessment area is categorised as low to medium. Soluble rock risk is also indicated in the south of the section.

48) GI reporting was incomplete at the time of writing. Available draft unchecked borehole logs were provided, the locations of which are shown on Figure 7.4 and Figure 7.5. Some boreholes are situated outside of the groundwater assessment area due to access limitations from inaccessible terrain. Initial draft GI data are available for the Newton-in-Bowland portal at the proposed location; however, no information is available at the Lower Houses Compound shaft due to access issues. Instead, the closest available data from the Lower Houses shaft are from T03_4B_BH003, located 445 m from the Proposed Bowland Section and 677 m from the shaft location. The available GI data together with BGS mapping suggest that the superficial deposits present at both shaft and portal locations are glacial till (diamicton). Bedrock differs at shaft locations; however, mudstone is recorded by the closest available GI borehole from the Lower Houses shaft (some 677 m away), which seems to be correlated with the Millstone Grit Group indicated by the BGS mapping, and limestone beds with relatively thin beds of mudstone are recorded at the Newton-in-Bowland portal suggesting the formation is principally limestone. The data suggest both shaft and portal locations are underlain by superficial deposits of Secondary Undifferentiated aquifer grade and bedrock that is of Secondary A aquifer grade.

49) Selected draft unchecked boreholes along the Proposed Bowland Section tunnel indicate the bedrock geology at the depth of the construction (170.1 to 175.5 mAOD). The presence of mudstone, siltstone and sandstone at boreholes BH003, BH009, BH011B and BH015B suggest that the Millstone Grit Group is present in the central and northern areas of the Proposed Bowland Section. Boreholes located to the south (BH017 and BH019) indicate the presence of limestone (silty clayey limestone and limestone with siltstone laminations). The data suggest the tunnel would be located within Secondary A aquifer grade bedrock.

50) Shallow[12] and deep[13] geophysical sections along the route are presented in Appendix 7.5 providing additional lithology information and structural data. Section locations are displayed on Figures 7.4 and 7.5. Shallow sections typically reached 50 mbgl and were recorded close to the shaft and portal locations. Deep sections typically reached depths of more than 1000 mbgl and were recorded along the majority of the length of the Proposed Bowland Section tunnel, albeit the routing did not follow the tunnel alignment because of topography and access issues.

51) Lithology information from deep geophysics is not detailed enough for the purpose of this assessment; however, major faults can be identified.

52) Detailed lithology information is provided for shallow sections. However, no clear distinction was made between various bedrock layers present (i.e. sandstone, siltstone and mudstone) in section S001;

[12] Fugro Geoservices Limited (2020a) *T03 Shallow Geophysical Survey Interpretive Report. Haweswater Aqueduct Resilience Project (HARP).* For United Utilities Water Limited. Draft for Client Comment. Fugro Document No.: D19020-T03-S-INT 01.

[13] Fugro Geoservices Limited (2020b) *Haweswater Aqueduct Resilience Programme (HARP) Deep Seismic Investigation T03 – Interpretive Report*. For United Utilities Water Limited. Fugro Document No.: D19020-T03-D-INT 02.

therefore, no additional bedrock formation information can be extracted from geophysics data in proximity to the Lower Houses shaft.

53) Geological formations of limestone and mudstone are defined in shallow section interpretations (S002 and S004) close to the Newton-in-Bowland Compound portal, which closely correlates with information provided by the BGS (BGS, 2020)[14] and reported above.

54) Data of relevance for this assessment from geophysics sections are summarised in Table 7.14.

Table 7.14: Available Data from GI Geophysics Sections Used for this Assessment

	Shallow Geophysical Sections	Deep Geophysical Sections
Lower Houses Compound shaft	Major faults and identification of areas of granular glacial till	Major faults only
Proposed Bowland Tunnel	Not known – Shallow sections would not cover the tunnel route at required depths	
Newton-in-Bowland Portal	Major faults; formation differentiation between the Chatburn Limestone, Hodder Mudstone and Helton Beck Limestone; and presence of void spaces in limestone	

55) The presence of granular glacial till, void spaces and fault discontinuities are typically indicators of areas of higher permeability (or hydraulic conductivity). Granular glacial till is frequently found within the 1 km buffer zone of the Lower Houses shaft based on shallow geophysical data, including within the Proposed Bowland Section . At the Newton-in-Bowland Compound, shallow geophysical data indicate the presence of glacial till in proximity to the portal although it is not described as granular. Where limestone is identified along the section within 1 km of the Newton-in-Bowland Compound portal in the shallow geophysical data, dry and wet rock voids are recorded, approximately 20 m to 30 m in length; one being located within the Proposed Bowland Section around the portal roughly 3 to 5 mbgl.

56) Values for hydraulic conductivity are indicated from draft unchecked GI packer test data varying from 0.0034 m/d in siltstone to 0.70 and 0.73 m/d in fractured sandstone and fractured mudstone respectively as shown in Table 7.15.

[14] British Geological Society (2020) Geology of Britain Viewer [Online] Available from: http://mapapps.bgs.ac.uk/geologyofbritain/home.html [Accessed: January to July 2020].

Table 7.15: Hydraulic Conductivity Results from Packer Tests Taken from the GI Data Package

Shaft, Portal or Tunnel	Borehole	Depth Range		Geology Summary	Average Hydraulic Conductivity from Packer Tests (m/d)
		mbgl	mAOD		
Proposed Bowland Section tunnel	BH015B	70.2 to 72.2	199.8 to 197.8	Thinly laminated to thickly bedded fine to course grained sandstone with fractures	0.703
		80.2 to 82.2	189.8 to 187.8	Thinly laminated to thinly bedded silty mudstone with fractures	0.733
	BH017	21 to 23	180 to 178	Thinly laminated to thickly bedded, silty, clayey limestone with discontinuities	0.113
	BH019	35.5 to 37.5	170.5 to 168.5	Thinly laminated to thinly bedded siltstone with laminated limestone containing fossils. Contains discontinuities	0.00344
		42 to 44	164 to 162	Thinly laminated to thinly bedded limestone with thinly laminated to thinly bedded mudstone. Contains fossil debris and discontinuities	0.192
	BH020	38 to 40	172 to 170	Not known -– Borehole log descriptions not provided	0.218

58) Some draft unchecked groundwater-level data are available at the time of writing. Minimum depth to groundwater information recorded from 17 February to 25 March 2020 is used for this assessment for 10 monitoring locations within 1.7 km of the Proposed Bowland Section (proposed shaft, portal or tunnel locations).

59) Piezometric groundwater-level measurements taken closest to the depth of the Proposed Bowland Section tunnel varied significantly between 2.8 and 30.0 mbgl (minimum and maximum as 174 and 374 mAOD). Exceptions are observed for boreholes BH009 and BH015B at 52.9 and 75 mbgl respectively. For a few of the boreholes, dual measurements are available with multiple piezometers used at different depths in one same location. Both downward and upward groundwater gradients were recording, depending on locations, indicating semi-confined aquifer conditions could be present in some areas along the length of the Proposed Bowland Section.

60) Estimated groundwater levels along the length of the existing aqueduct are shown in profile sections reported by Preene Groundwater Consulting Ltd,[15] copies of which are presented in Appendix 7.5. Groundwater levels at the existing aqueduct are reported to range from 190 to 340 mAOD.

61) Five GI boreholes in the northern and southern areas are also situated close to the existing aqueduct. Therefore, a comparison (Table 7.16) can be made with groundwater-level data estimated in sections produced by Preene Groundwater Consulting Limited[16] in Appendix 7.5. The difference observed typically ranged between 10 m and 20 m, at the exceptions of BH003 and BH015B with differences of approximately 2 m and 70 m respectively.

[15] Preene Groundwater Consulting Limited (2014) *Haweswater Aqueduct Hydrogeological Desk Study Interim Report.* Reference: 14-142.102.V1. Status: ISSUE.
[16] *Ibid.*

Table 7.16: Comparison of Groundwater Levels. From GI Boreholes and Sections by Preene Groundwater Consulting Ltd (2014)[17]

Boreholes Located Close to the Existing Aqueduct (within 155 m)	Approximate Groundwater Levels (mAOD)	
	GI Borehole Maximum Recorded Measurements	Data by Preene Groundwater Consulting Ltd (2014)
BH003	198	200
BH015B	190	260
BH019	196	210
BH020	190	210
BH021	174	190

62) Many springs are indicated within the groundwater assessment area as shown on Figure 7.6. This is based on information gathered from Ordnance Survey maps, historical BGS borehole data documented by Preene Groundwater Consulting Ltd[18] and springs recorded from recent GWDTE surveys. The majority of springs are found in the north-most and south-most areas of the Proposed Bowland Section, with relatively few located in the central area where topography is significantly higher. Several in the northern section are located within 200 m of the existing aqueduct, suggesting that groundwater levels are likely to be shallow close to the existing aqueduct in this area. It is unclear whether all these springs are still active or whether some of them are historical features which are now dry. However, along much of the route of the existing aqueduct, groundwater levels appear to be at some depth below ground level, suggesting that groundwater connection to surface water features and springs may be limited.

63) No licensed groundwater abstractions are recorded within the groundwater assessment area. However, the western part of the Proposed Bowland Section and wider groundwater assessment area encroach upon both an SPZ2 and SPZ3 as shown on Figure 7.6. In this general area, borehole yields between 432 m3/d to 864 m3/d can be expected within the Millstone Grit Group aquifers, but with significantly higher yields of up to 4,320 m3/d in the Pendle Grit Member.[19]

64) Sixteen PWS have been recorded within the groundwater assessment area as shown on Figure 7.6 and Table 7.17 based on information provided by landowners. This information includes feedback from landowner questionnaires available at the time of writing. N.B. due to their distance from the scheme, PWS3-5 and PWS3-6 are not shown on Figure 7.6.

Table 7.17: PWS within the Groundwater Assessment area

Private Water Supply Label	Approximate Distance from the Proposed Bowland Section (m)	Closest Features	Type	Depth	Comments
PWS3-1	250	Proposed Bowland Section tunnel (close to Lower Houses Compound)	Borehole	45 m	The supply is for domestic use and farm buildings. It only supplies the Botton Farm property. Supply is eight years old and equipped with a pumping system.
PWS3-2	265	Proposed Bowland Section tunnel	Borehole	Not known	No further information for this borehole was available.

[17] Preene Groundwater Consulting Limited (2014) *op. cit.*
[18] *Ibid.*
[19] ABESSER, C., SHAND, P. and INGRAM, J. (2005) *Baseline Report Series: 18. The Millstone Grit of Northern England*. British Geological Survey Commissioned Report. No.CR/05/015N.

Private Water Supply Label	Approximate Distance from the Proposed Bowland Section (m)	Closest Features	Type	Depth	Comments
		(close to Lower Houses Compound)			
PWS3-3	595	Proposed Bowland Section tunnel	Borehole	Not known	No further information for this borehole was available.
PWS3-4	640	Proposed Bowland Section tunnel	Borehole	Not known	No further information for this borehole was available.
PWS3-5	2,170	Proposed Bowland Section tunnel	Spring	Not known	Supplies other properties including Woodhouse Gate Farm. No further information available.
PWS3-6	1,830	Proposed Bowland Section tunnel	Spring	Not known	No further information available.
PWS3-7	100	Proposed Bowland Section tunnel	Borehole	Not known	No further information available.
PWS3-8	0	Newton-in-Bowland Compound	Spring	Not known	Serves several properties in the area. No further information available. Unclear whether this could be part of the same supply as PWS3-15. No further information available.
PWS3-9	480	Lower Houses Compound	Borehole	Not known	PWS3-9 provides a domestic supply to High Park House (plus potentially other houses) and a supply to farmyard buildings.
PWS3-10	435	Lower Houses Compound	Spring	Not known	PWS3-10 supplies the property's field troughs. No further information available.
PWS3-11	505	Lower Houses Compound	Spring	Not known	PWS3-11 supplies the property's field troughs. No further information available.
PWS3-12	160	Lower Houses Compound	Borehole	Not known	PWS3-12 provides a domestic supply to High Park House (plus potentially other houses) and a supply to farmyard buildings.
PWS3-13	50	Newton-in-Bowland Compound	Spring	Not known	Supplies Gamble Hole Farm, Gamble Hole Barn and Higher House Barn. No further information available. Water is pumped up to a holding tank

Private Water Supply Label	Approximate Distance from the Proposed Bowland Section (m)	Closest Features	Type	Depth	Comments
					and then gravity fed to property and buildings.
PWS3-14	0	Newton-in-Bowland Compound	Spring	Not known	Supplies Knowlmere Estate used for domestic supply and farm. Knowlmere Estate covers a large geographical area as shown on Figure 7.6. Supply fluctuates but does not dry out.
PWS3-15	0	Newton-in-Bowland Compound	Spring	Not known	Supplies Fober Farm as domestic supply and used to supply more than 200 cattle.
PWS3-16	0	Lower Houses Compound	Unknown	Not known	A water supply was indicated in the northern end of the land owned by Botton Farm (PWS3-1) in the PWS questionnaire; however, no further information was available.

Groundwater Dependent Terrestrial Ecosystems

65) Eight GWDTE sites have been identified within the refined GWDTE assessment area (see Figure 7.7). One of the sites has a high sensitivity, six sites contain areas of medium sensitivity and two sites contain areas where the sensitivity is considered to be low. A summary of the sites in relation to the Proposed Bowland Section, their determined groundwater dependency classification, ecological designation and corresponding sensitivity is shown in Table 7.18.

66) 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 7.18: Summary of GWDTEs within the Refined GWDTE Assessment area

Site Name	Approximate Shortest Distance from Proposed Bowland Section (m)	Closest Feature	Assessment of Groundwater Dependency and Ecological Designation	Sensitivity
Lower House Cottage	5	Lower Houses Compound and open-cut connection	Moderate to low (with no designation)	Medium to low
Lower House Cottage West	25	Lower Houses Compound and attenuation pond	Moderate (with no designation)	Medium
Park House Lane	1	Lower Houses Compound access track	Moderate to low (with no designation)	Medium to low
Gamble Hole Farm Pasture	0	Newton-in-Bowland Compound, T03/C portal, access tracks, open-cut connection	High (with Biological Heritage Site designation)	High

Site Name	Approximate Shortest Distance from Proposed Bowland Section (m)	Closest Feature	Assessment of Groundwater Dependency and Ecological Designation	Sensitivity
		and overflow connection		
The Coach House	5	Newton-in-Bowland Compound	Moderate (with no designation)	Medium
Dunsop Bridge Road	0	Newton-in-Bowland Compound access track	High to moderate (with no designation)	Medium
River Hodder North	0	Newton-in-Bowland Compound access track	High to moderate (with no designation)	Medium
River Hodder South	45	Newton-in-Bowland Compound access track	Moderate (with no designation)	Medium

7.5.3 Water Framework Directive

67) Fifteen WFD surface water bodies and two WFD groundwater bodies fall within the assessment area. Of these, 13 WFD surface water bodies have been scoped out based on distance from, or lack of hydraulic connectivity to, the Proposed Bowland Section components and likelihood of potential long-term effects.

68) 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

69) The features and the assigned sensitivities for the water environment have been summarised in Table 7.19.

Table 7.19: Summary of Sensitivity

Feature Name	Sensitivity	Description
Fluvial Geomorphology		
River Hindburn (W478)	Very high	A meandering channel with a range of geomorphological processes and features. No modifications.
River Hodder (W477)	Medium	A meandering channel with a range of geomorphological processes and features. Extensive modifications.
Cod Gill (W206)		A sinuous channel with limited geomorphological processes or features. Some modifications including extensive straightening. Partly based on desk-based observations.
Unnamed Watercourse 385 (W462)		A sinuous channel with limited geomorphological processes or features. No modifications.
Unnamed Watercourse 169 (W215)	Low	A straight channel with no geomorphological processes or features. No modifications.
Unnamed Watercourse 384 (W461)		A sinuous channel with no geomorphological processes or features. Some modifications.

Feature Name	Sensitivity	Description
Unnamed Watercourse 386 (W463)		Desk-based observations. A straight channel with no geomorphological processes or features. Limited modifications.
Surface Water Quality		
River Hindburn (W478)	Very high	Lies outside 500 m assessment area (~600 m from site compound boundary) but is a WFD-classified water body and justifies inclusion in the impact assessment. The River Hindburn holds overall, chemical and ecological status of good and high status for physico-chemical as well as good status for biological quality elements.
Cod Gill (W206) Unnamed Watercourse 163 (W207) Unnamed Watercourse 169 (W215)	Medium	Not classified under WFD. Hydrologically connected and a mainstem tributary of the River Hindburn.
River Hodder (W477)	Very high	The River Hodder holds overall, chemical and ecological status of good and high status for physico-chemical as well as good status for biological quality elements.
Heaning Brook (W460) Unnamed Watercourse 384 (W461) Unnamed Watercourse 385 (W462)	Medium	Not classified under WFD but hydrologically connected and a mainstem tributary of the River Hodder.
Unnamed Watercourse 386 (W463) Unnamed Watercourse 1312 (W1382)	Low	Not classified under WFD. Assessed to be artificial drainage channel.
Surface water habitat (Lowland Fen) centred on NGR SD 68696 50425 (indicating good water quality)	Medium	Contains BAP habitat. For consideration of Gamble Hole Farm Pasture GWDTE see Groundwater.
Groundwater		
Millstone Grit Group	High	Fine to very coarse-grained sandstones, interbedded with siltstones and mudstones, with subordinate shaley mudstone, claystone, coals and seat earths.
Chatburn Limestone Formation	High	Well-bedded packstone limestones, with chert lenses and subordinate thin beds of shaley mudstone and siltstone.
Hodder Mudstone Formation	High	Mudstone, with subordinate detrital limestone, siltstone and sandstone. Mudmound reef limestones, limestone boulder conglomerates and breccias near the base.

Feature Name	Sensitivity	Description
Clitheroe Limestone Formation	High	Packstones, wackestones and subordinate grainstones and mudstones with reef limestones.
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.
Pendleton Formation	High	Fine to very coarse-grained pebbly sandstone, interbedded with siltstone and mudstone and subordinate shales, thin coals and seatearths.
Silsden Formation		
Bowland 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.
Head	Medium	Comprises sand and gravel, locally with lenses of silt, clay or peat and organic material.
Alluvium	High	Typically soft to firm, consolidated, compressible silty clay, that 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.
Peat	Low	An accumulation of wet, dark brown, partially decomposed vegetation, or an organic rich clay.
River terrace deposits	High	Sand and gravel, locally with lenses of silt, clay or peat.
Talus	High	Clast-supported accumulation of angular rock fragments.
Glaciofluvial sheet deposits	High	Sand and gravel, locally with lenses of silt, clay or organic material.
PWS	High	Fifteen PWS feeding fewer than 10 properties.
Lower House Cottage	Medium to low	GWDTE with areas of moderate and low groundwater dependency (no ecological designation).
Lower House Cottage West	Medium	GWDTE with a moderate groundwater dependency (no ecological designation).
Park House Lane	Medium to low	GWDTE with areas of moderate and low groundwater dependency (no ecological designation).
Gamble Hole Farm Pasture	High	GWDTE with a high groundwater dependency (Biological Heritage Site).
The Coach House	Medium	GWDTE with a moderate groundwater dependency (no ecological designation).
Dunsop Bridge Road	Medium	GWDTE with areas of high and moderate groundwater dependency (no ecological designation).

Feature Name	Sensitivity	Description
River Hodder North	Medium	GWDTE with areas of high and moderate groundwater dependency (no ecological designation).
River Hodder South	Medium	GWDTE with a moderate groundwater dependency (no ecological designation).

7.6 Assessment of Likely Significant Effects

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

7.6.1 Enabling Works Phase

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

Fluvial Geomorphology

72) The enabling phase of the Proposed Bowland 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)
- Construction of culverts for temporary access routes
- Construction of bridges for temporary access routes.

73) 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
- Dewatering.

Increased Fine Sediment Input

74) Unnamed Watercourse 169 would be crossed by the access route to Lower Houses Compound. Given the basic nature and limited range of geomorphological features and processes observed on this watercourse, it would be unlikely to be sensitive to changes in fine sediment input. Therefore, the impact on Unnamed Watercourse 169 of an increase in fine sediment input would likely be negligible, with a neutral significance of effect.

75) The River Hindburn is 800 m downstream of Lower Houses Compound and receives flow from Unnamed Watercourse 169, which is crossed by the access route to Lower Houses Compound. The River Hindburn has been assessed due to its very high sensitivity and large number of significant geomorphological features. The effect on the River Hindburn would likely be minimised by embedded mitigation measures (employed on Unnamed Watercourse 169) and the distance between the River Hindburn and the Proposed Bowland Section. Therefore, any impacts due to increased fine sediment input (i.e. smothering of coarse bed substrate) would likely be minor with a moderate significance of effect.

76) The River Hodder would be crossed by the access route to the Newton-in-Bowland Compound. The crossing would be via a clear span bridge. The River Hodder exhibited several coarse sediment geomorphological features, which could be smothered by fine sediment. However, as the crossing is proposed to be a clear span bridge rather than a culvert, the input of fine sediment is likely to be low. Therefore, the impact of changes in supply of fine sediment would likely be minor. The sensitivity of this watercourse is high; therefore, the significance of the effect would be slight.

77) Unnamed Watercourse 384 would be crossed twice by the access route to Newton-in-Bowland Compound, whilst Unnamed Watercourse 385 and Unnamed Watercourse 386 would each be crossed once. Given the basic nature and limited range of geomorphological features and processes observed on these watercourses, they would be unlikely to be sensitive to changes in fine sediment input. Therefore, the effect on Unnamed Watercourse 384, Unnamed Watercourse 385 and Unnamed Watercourse 386 of an increase in fine sediment input would likely be negligible, with a neutral significance of effect.

Changes to Flow Regime

78) Drainage (construction and surface water runoff) from Lower Houses Compound would flow into Cod Gill 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 6.4 litres per second (l/s). Discharge to Cod Gill would be attenuated to 6 l/s, allowing for a maximum permissible discharge approximately 0.4 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.

79) Drainage (construction and surface water run-off) from Newton-in-Bowland Compound would flow into the River Hodder through the overflow structure, 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 9.7 l/s. Discharge to the River Hodder would be attenuated to 10 l/s, allowing for a maximum permissible discharge approximately 0.3 l/s greater than would be encountered under baseline conditions. This represents a small increase in runoff; however, as the River Hodder is prone to erosion there would likely be a minor impact with a slight significance of effect.

80) Drainage from the Newton-in-Bowland Compound access route would flow into Unnamed Watercourse 386 through two temporary outfalls and the River Hodder through a further two temporary outfalls. The discharge from the outfalls could change the flow regime and potentially cause erosion of the bed and opposite banks. No information has been provided on the discharge rates from these outfalls. At the location of the temporary outfalls on Unnamed Watercourse 386 no erosion was observed; therefore, there would likely be a negligible effect on this watercourse with a neutral significance of effect. Erosion was seen on the River Hodder at the location of the temporary outfalls. In addition, the two outfalls would be on opposite banks from each other which could lead to localised scour. Therefore, there would likely be a moderate impact on the River Hodder with a moderate significance of effect.

81) The temporary culvert crossing on Unnamed Watercourse 169 could change the flow regime within the watercourse due to flows funnelling through the culvert. This could disturb morphological features up and downstream of the culvert. However, as few significant geomorphological features or processes were seen on this watercourse, the impact on Unnamed Watercourse 169 would likely be negligible with a neutral significance of effect.

82) The temporary bridge crossing on the River Hodder would be clear span and would not interact with the watercourse under normal flow conditions. In addition, during flood conditions, although there would be changes to floodplain flows, as the bridge would be clear span, it is not anticipated that there would be changes in channel flow. Therefore, the impact on flow would likely be negligible with a neutral significance of effect.

83) The temporary culvert crossing on Unnamed Watercourse 386 could change the flow regime within the watercourse due to flows funnelling through the culvert. This watercourse was not visited; however, it is anticipated that few significant geomorphological features or processes would be present. Therefore, the impact on Unnamed Watercourse 386 would likely be negligible, with a neutral significance of effect.

84) The two temporary culvert crossings on Unnamed Watercourse 384 could change the flow regime within the watercourse due to flows funnelling through the culverts. Although few significant geomorphological features were seen on this watercourse, the watercourse is crossed twice. Therefore, the impact on Unnamed Watercourse 384 would likely be minor, with a neutral significance of effect.

85) The temporary culvert crossing on Unnamed Watercourse 385 could change the flow regime within the watercourse due to flows funnelling through the culvert. However, as few significant geomorphological features or processes were seen on this watercourse, the impact on Unnamed Watercourse 385 would likely be negligible, with a neutral significance of effect.

86) The flow regime in the River Hodder and Unnamed Watercourse 386 is impacted by more than one activity in the Proposed Bowland Section. Therefore, the greatest impact has been used.

Loss of Riparian Vegetation

87) Construction of the access route to Lower Houses Compound would require the clearance of riparian vegetation along Unnamed Watercourse 169. The riparian vegetation on this watercourse is grasses and sedges and is unlikely to be significantly aiding bank stability. Therefore, the impact of vegetation removal on Unnamed Watercourse 169 would likely be negligible with a neutral significance of effect.

88) Construction of the access route to Newton-in-Bowland Compound would require the clearance of riparian vegetation on the River Hodder, Unnamed Watercourse 384 and Unnamed Watercourse 386. The riparian vegetation on these watercourses consisted of grass and occasional bushes and trees and is unlikely to be significantly aiding bank stability. Therefore, the impact of vegetation clearance would likely be negligible with a neutral significance of effect.

89) Construction of the access route to Newton-in-Bowland Compound would require the clearance of riparian vegetation on Unnamed Watercourse 385. The riparian vegetation on Unnamed Watercourse 385 consisted of grass, sedge and a semi-continuous line of trees. Some lateral adjustment was seen on this watercourse, which could increase following vegetation removal. Therefore, the impact of vegetation clearance would likely be minor with a slight significance of effect.

Disturbance of Channel Bed and Banks

90) Temporary outfall construction could disturb bed and bank features and cause compaction of bed substrate on Cod Gill. The location of the temporary outfall was not visited during the site visit; however, desk-based observations suggest a limited range of geomorphological features would be present. Therefore, construction of a temporary outfall would likely have a minor impact, with a slight significance of effect.

91) Culvert construction could cause compaction of bed substrate and disturbance of channel features on Unnamed Watercourse 169. The watercourse exhibited a limited range of geomorphological features which would be unlikely to be sensitive to disturbance. Therefore, culvert construction for the Lower Houses Compound access route would likely have a negligible impact with a neutral significance of effect.

92) Temporary outfall construction and positioning could disturb bed and bank features and cause compaction of bed substrate on the River Hodder. This watercourse exhibited a range of sensitive geomorphological features which could be lost, disturbed or degraded as a result of construction activities. This would likely have a moderate impact, with a moderate significance of effect.

93) Temporary culvert construction could disturb bed and bank features and cause compaction of bed substrate on Unnamed Watercourse 384. Although few significant geomorphological features were seen on this watercourse, the watercourse is crossed twice. Therefore, there would likely be a minor impact, with a neutral significance of effect.

94) Culvert construction could cause compaction of bed substrate and disturbance of channel features on Unnamed Watercourse 385. The geomorphological features seen on this watercourse were limited. Therefore, there would likely be a minor impact, with a slight significance of effect.

95) Culvert construction could cause compaction of bed substrate and disturbance of channel features on Unnamed Watercourse 386. The geomorphological features seen on this watercourse were limited. Therefore, there would likely be a minor impact, with a neutral significance of effect.

Dewatering

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

Surface Water Quality

97) During the enabling phase of the Proposed Bowland 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 (including topsoil stripping and earthworks, provision for compound drainage and SuDS, and creating areas of hardstanding)
- Construction of temporary access routes (including earthworks and associated drainage)
- In addition to the new access tracks, the development of the Newton-in-Bowland Compound would also involve the construction of a temporary clear span bridge over the River Hodder to facilitate access to the site
- Construction of 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.

98) Without any specific 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.

Sediment Laden Runoff

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

100) 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.

101) For the Lower Houses Compound and associated access route this would have the potential to impact tributaries of the River Hindburn (Cod Gill and Unnamed Watercourse 169). Furthermore, site drainage would be discharged to Cod Gill. Given its location in relation to the site compound it is anticipated that for Unnamed Watercourse 163, the potential impacts related to sediment laden runoff are likely to be limited to areas of material storage.

102) For the Newton-in-Bowland Compound and associated access route this would have the potential to impact tributaries of the River Hodder (Heaning Brook, Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312) as well as the River Hodder. Soil storage areas would be located within the vicinity of Unnamed Watercourse 384. Soil storage areas would be sited within an acceptable distance from any watercourses as defined in the CCOP. This distance would be large enough to ensure potential impacts from sediment laden runoff sourced from soil storage areas would be minimised. Furthermore, site drainage would be discharged

to the existing Well House drain associated with the existing aqueduct and Unnamed Watercourse 386, both of which eventually discharge into the River Hodder.

103) For watercourses associated with the Lower Houses Compound, the magnitude of impact would be minor for Cod Gill and Unnamed Watercourse 169. Given its location from potential site activities the magnitude of impact from sediment laden runoff would be negligible for Unnamed Watercourse 163. This would result in a slight significance of effect for Cod Gill and Unnamed Watercourse 169, and a neutral significance of effect for Unnamed Watercourse 163.

104) All scoped-in watercourses at the north end of the Proposed Bowland Section ultimately flow into the River Hindburn. Due to the overall distance between source and receptor (River Hindburn) and the combined dilution capacity of the tributaries, the cumulative effect of sediment laden runoff would likely have a negligible magnitude of impact which would result in a neutral significance of effect on the River Hindburn.

105) For watercourses associated with the Newton-in-Bowland Compound, the magnitude of impact of sediment laden runoff would be minor for Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312. For Heaning Brook the magnitude of impact of sediment laden runoff would be negligible due to dilution capacity. The respective assigned magnitudes of impacts above would result in a slight significance of effect for Unnamed Watercourse 384 and Unnamed Watercourse 385. A neutral significance of effect is reported for Heaning Brook, Unnamed Watercourse 386 and Unnamed Watercourse 1312.

106) All scoped-in watercourses associated with the south of the Proposed Bowland Section flow into the River Hodder. The River Hodder would have significant dilution capacity to mitigate / buffer against any discharges it receives from sediment laden runoff and treated site drainage. Furthermore, there would be the clear span bridge installed across the River Hodder to facilitate access to the Newton-in-Bowland Compound. The required activities associated with the installation of the clear span bridge could generate sediment laden runoff arising from ground stripping and abutment formation that could reach the River Hodder. The effect of sediment laden runoff on the River Hodder would be a minor magnitude of impact. This would result in a moderate significance of effect on the River Hodder.

<u>Chemical Pollution</u>

107) During the enabling works phase, several potential pollutants would be present, including oils, fuels, chemicals, cement and concrete, 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.

108) The impact of any chemical pollution incident on surface water quality would depend on the volume of the spill / leak as well as the flow 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.

109) For the Lower Houses Compound and associated access routes this would have the potential to impact tributaries of the River Hindburn (Cod Gill and Unnamed Watercourse 169). For the Newton-in-Bowland Compound and associated access routes this would have the potential to impact tributaries of the River Hodder (Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312).

110) Similar to the assessment of potential sediment laden runoff impacts, the risks of chemical pollution affecting Unnamed Watercourse 163 and Heaning Brook would be anticipated to be reduced in comparison with other listed watercourses. This is due to their distance from and proportion of site drainage they would receive, relative to both respective site compounds.

111) For watercourses associated with Lower Houses Compound, the magnitude of impact for chemical pollution would be minor for Cod Gill and Unnamed Watercourse 169 and negligible for Unnamed Watercourse 163. This assumes that the CCoP (Appendix 3.2) would be adhered to including mitigation for chemical spills and fuel leaks. This would result in a slight significance of effect for Cod Gill and Unnamed Watercourse 169 and a neutral significance of effect for Unnamed Watercourse 163.

112) All scoped-in watercourses that are at the north of the Proposed Bowland Section flow into the River Hindburn. Due to the overall distance and dilution capacity of the tributaries and the River Hindburn itself, the cumulative effect of chemical pollution would likely have a negligible magnitude of impact, resulting in a neutral significance of effect on the River Hindburn.

113) For watercourses associated with Newton-in-Bowland Compound, the magnitude of impact for chemical pollution would be anticipated to be minor for Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312 and negligible for Heaning Brook. This would result in a slight significance of effect for Unnamed Watercourse 384 and Unnamed Watercourse 385 and a neutral significance of effect for Heaning Brook, Unnamed Watercourse 386 and Unnamed Watercourse 1312.

114) All scoped-in watercourses associated with the south of the Proposed Bowland Section flow into the River Hodder. The River Hodder would have significant dilution capacity to mitigate / buffer against chemical pollution. The magnitude of impact on the River Hodder would be negligible. This would result in a neutral significance of effect on the River Hodder.

<u>Bed and Bank Disturbance</u>

115) Activities associated with the enabling phase of the Proposed Bowland 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 install 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.

116) One culvert would be required to be installed (Unnamed Watercourse 169) associated with the Lower Houses Compound. Four culverts would be required to be installed (Unnamed Watercourse 384 at two locations, Unnamed Watercourse 385 and Unnamed Watercourse 386) associated with the Newton-in Bowland-Compound.

117) The temporary clear span bridge structure, which would be required to facilitate site access across the River Hodder, would not be anticipated to affect the banks or bed of the channel. As a result, no impacts to the River Hodder are anticipated.

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

119) Due to the requirement for associated culvert crossings and / or near channel working on Unnamed Watercourse 169, the magnitude of impact of bed and bank disturbance would be minor. This would result in a slight significance of effect for Unnamed Watercourse 169.

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

121) Due to the requirement for associated culvert crossings and / or near channel working on Unnamed Watercourse 384 at two locations, Unnamed Watercourse 385 and Unnamed Watercourse 386, the magnitude of impact of bed and bank disturbance would be minor. This would result in a slight significance of effect for Unnamed Watercourse 384 and Unnamed Watercourse 385, and a neutral significance of effect for Unnamed Watercourse 386.

Impacts to Surface Water Habitats

122) One surface water habitat has been identified within the assessment area associated with the Newton-in-Bowland Compound. This identified habitat (NGR SD 68696 50425) consists of an area of Lowland Fen (indicating good water quality) which would lie within the drainage catchment of the access track footprint and could be impacted by the activities outlined above (sediment laden runoff and chemical pollution). The access track would bisect the habitat and there could be potential issues relating to the continued (hydrological) connectivity of the wetland.

123) As a result of the potential impacts outlined, the magnitude of impact on the area of Lowland Fen would be anticipated to be moderate resulting in a significance of effect of moderate.

Groundwater

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

Groundwater Flow

125) 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
- Earthwork associated with site compound construction
- Earthwork associated with access roads.

126) During the enabling phase, two works are proposed that would involve excavation deeper than 1 m. These are the attenuation ponds at Lower Houses Compound and Newton-in-Bowland Compound, which are expected to be excavated to depths of 2 m. In addition, shallower excavations may be required to construct access tracks within the Newton-in-Bowland Compound; these would be a maximum of 1 m deep.

127) There is uncertainty on groundwater levels in superficial deposits (medium sensitivity) in the vicinity of the Lower Houses Compound and Newton-in-Bowland Compound from the initial draft GI data, and the nearest bedrock groundwater-level monitoring locations are recording variable depths in bedrock. With the two attenuation ponds located downgradient to the monitored locations, groundwater levels have been conservatively assumed to be 1 m below ground in these areas. The dewatering of these two excavations would therefore generate a potential localised impact on groundwater in till (minor magnitude at the scale of the aquifer), resulting in a potential significance of effect of slight on superficial deposits.

128) Excavations for the access tracks at Newton-in-Bowland Compound would not be expected to intercept groundwater. All other works within the planning application boundary would be expected to have negligible impact on groundwater flows within superficial deposits, resulting in potential neutral significance of effect.

129) The initial draft GI data suggest a thin cover of drift deposits at Newton-in-Bowland Compound and access track indicating that excavation works proposed in this location could reach the top of the bedrock for the Newton-in-Bowland Compound attenuation pond. Any corresponding impacts on bedrock groundwater (high sensitivity) would be expected to be of negligible magnitude, which would result in a potential significance of effect of neutral. Due to the expected thickness of superficial deposits, no dewatering impact would be expected on bedrock at the Lower Houses Compound.

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

131) The Sichardt method (e.g. Preene et al., 2016)[20] was used to estimate the dewatering radius of influence around each excavation expected to intercept groundwater. This was applied using the estimated drawdown of groundwater levels to the base of the excavation. Hydraulic conductivity values used for each excavation calculation were obtained from generic values from the scientific literature (Domenico and Schwartz, 1990)[21] appropriate to the materials recorded during the GI where in-situ testing was not available. This approach was used as permeability tests (e.g. packer tests) were not available, at the time of writing, in boreholes in the vicinity of the proposed excavation areas for shaft and portal assessment (see Table 7.15).

132) 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.

133) 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 7.6, conducted using 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 and water-level data from the initial draft GI data. Additional details on the assessment of impact on GWDTE, site by site, are provided in Appendix 7.2.

134) As shown in Appendix 7.6, the closest PWS, PWS3-12 and PWS3-16, are expected to be located outside of the calculated radius of influence of any groundwater drawdown (about 350 m and 200 m downgradient to Lower Houses Compound attenuation pond respectively). PWS3-12 is expected to be a borehole, albeit its exact location and depth have not been confirmed. The type of supply is unknown for PWS3-16. Potential flow impacts on these supplies are unlikely; however, given the remaining uncertainties the potential magnitude of impact is categorised at negligible resulting in a potential significance of effect of neutral.

135) In terms of surface water features, only Unnamed Watercourse 384 (low sensitivity) within the Newton-in-Bowland Compound would be expected to be impacted by dewatering during the enabling phase, as shown in Appendix 7.6. Situated approximately 8 m from the proposed attenuation pond, it would exist within the zone of influence of groundwater drawdown resulting in a localised, small-scale reduction in resource availability categorised as a moderate magnitude impact. The potential significance of effect for the Newton-in-Bowland attenuation pond on the nearby watercourse is therefore assessed as slight.

136) Groundwater dewatering can cause significant differential settlement effects on existing infrastructure and buildings. As shown in Appendix 7.6, one structure would be expected to be impacted during this phase of works, which is the Lunesdale North Well building (medium sensitivity) as it exists within the zone of influence of drawdown of the Lower Houses Compound attenuation pond, approximately 10 m away. Due to the localised, small-scale dewatering required for this construction, it would be categorised as a minor magnitude of impact, resulting in a potential significance of effect of slight.

137) The desk-based investigations have identified an area of disturbed ground, associated with the construction on the original / existing Haweswater Aqueduct, which for the purposes of a reasonable worst case assessment is assumed to be potentially contaminated. As shown in Appendix 7.6, the dewatering of the Newton-in-Bowland Compound attenuation pond could mobilise and capture the associated contaminant plume. The potential magnitude of impact would be considered minor due to the small amount of dewatering expected for attenuation ponds, resulting in a potential slight significance of effect for both superficial and bedrock aquifers.

138) Impacts to groundwater flow from compaction-related construction activities would be expected to occur during preparatory works within the red-line boundary red-line boundary. As shown in Appendix 7.6, this could lead to reduced flow capacity at PWS3-8, PWS3-14, PWS3-15 and PWS3-16 as they all potentially fall within the footprint of the Newton-in-Bowland Compound or, in the case of

[20] 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.
[21] Domenico, P.A. and Schwartz, F.W. (1990) *Physical and Chemical Hydrogeology*, John Wiley & Sons: New York.

PWS3-16, within the Lower Houses Compound. In addition, PWS3-16 could be impacted by the construction of the access road. PWS at the Newton-in-Bowland Compound are all described as spring fed, albeit this has not been verified with their exact location, and the supply type for PWS3-16 is unknown. Springs are very sensitive to sub-surface changes and there is also potential for the PWS infrastructure to be impacted. Given uncertainties, a conservative potential large significance of effect has been assessed for PWS3-8, PWS3-14, PWS3-15 and PWS3-16.

139) A reduction to baseflow at Unnamed Watercourse 384 and Unnamed Watercourse 385 would also be expected, each of neutral potential significance of effect.

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

141) Significant potential impacts on groundwater flows supporting GWDTEs are summarised in Table 7.20. 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.

Table 7.20: Summary of Potentially Significant Effects on GWDTE Groundwater Flows

Site Name	Sensitivity	Activity / Effect	Magnitude of Impact	Significance of Effect
Lower House Cottage	Medium to low	Intercept flows in short term, including ground compaction, topsoil stripping (groundwater levels / flows).	Moderate	Moderate – Significant
Gamble Hole Farm Pasture	High	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Major	Large – Significant
The Coach House	Medium	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Moderate	Moderate – Significant
River Hodder North	Medium	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (groundwater levels / flows).	Major	Large – Significant

<u>Groundwater Quality</u>

142) Soil stripping and vegetation clearance would take place around the shaft, portal, site compound areas and associated access roads. Ground disturbance from this soil-stripping activity, as well as earthworks associated with access road and SuDS construction, would potentially cause changes to groundwater quality due to mobilisation of soil and rock particles (suspended solids) and associated solutes which could migrate through the sub-soil and affect adjacent sensitive receptors (e.g. shallow groundwater abstractions and GWDTEs). 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) refers to measures associated with controlling silt pollution. Although, deeper excavations would create more direct pathway to the aquifer and these effects may extend somewhat further.

143) As per Table 7.1, potential impacts on aquifers from silt contamination have been scoped out. However, the assessment of the effects from these activities on groundwater receptors such as groundwater-fed PWS and GWDTEs are provided in Table 7.21. Groundwater abstraction sites potentially impacted by the effects of soil-stripping activity, as well as earthworks associated with access road and SuDS construction, would include PWS3-8, PWS3-12, PWS3-14, PWS3-15 and PWS3-16.

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

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
PWS3-8, PWS3-14 and PWS3-15	Medium	Major	Present within the Newton-in-Bowland Compound but away from direct works for the construction of the compound during the enabling works phase. Uncertainty remains, however, on the exact location of these features and springs are very sensitive to sub-surface changes.	Large – Significant
Spring PWS3-16	Medium	Major	Present within the Lower Houses Compound but away from direct works for the construction of the compound during the enabling works phase. Uncertainty remains, however, on the exact location for this feature and, if it is a spring, it would be very sensitive to sub-surface changes.	Large – Significant
Spring PWS3-12	Medium	Negligible	Present approximately 160 m downgradient from the Lower Houses Compound.	Neutral
No impact to other PWS or licensed abstractions would be expected.				
Gamble Hole Farm Pasture	High	Moderate	Present within the Newton-in-Bowland Compound. Embedded mitigation and good practice measures 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
River Hodder North	Medium	Moderate	Present within the Newton-in-Bowland Compound access track area. Embedded mitigation and good practice measures 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: predicted to receive slight or neutral effects, or no impacts at all.				

144) 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.

145) 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. These measures would reduce significantly the risks to groundwater quality impairment and associated receptors resulting from accidental spillages. The assessment of accidental spillages on aquifers and relevant receptors is provided in Table 7.22, taking into account the embedded CCoP (Appendix 3.2) measures.

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

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
Superficial aquifer – glacial till (diamicton)	Medium	Minor	Present at all compound and access track areas (Lower Houses Compound, Newton-in-Bowland Compound and within Newton-in-Bowland access track s).	Slight
Superficial aquifer – river terrace deposits	High	Minor	Present within Newton-in-Bowland access track.	Slight
Superficial aquifer – alluvium	High	Minor	Present within Newton-in-Bowland access track.	Slight
Secondary A bedrock aquifers	High	Negligible	Present at Proposed Bowland Section at Lower Houses and Newton-in-Bowland compounds.	Neutral
PWS3-12 borehole	Medium	Minor	Present approximately 160 m downgradient from the Lower Houses Compound.	Slight
PWS3-16 borehole	Medium	Major	Present within the Lower Houses Compound but away from direct works for the construction of the compound during the enabling works phase. Uncertainty remains, however, on the exact location for this feature and, if it is a spring, it would be very sensitive to sub-surface changes.	Large – Significant
PWS3-8, PWS3-14, PWS3-15	Medium	Major	Present within the Newton-in-Bowland Compound but away from direct works for the construction of the compound during the enabling works phase. Uncertainty remains, however, on the exact location of these features and springs are very sensitive to sub-surface changes.	Large – Significant
Gamble Hole Farm Pasture	High	Moderate	Present within the Newton-in-Bowland Compound. Embedded mitigation and good practice measures 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
River Hodder North	Medium	Moderate	Present within the Newton-in-Bowland Compound access track area. Embedded mitigation and good practice measures 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, or receive no impacts on groundwater quality.				

Summary of Effects

146) A summary of the enabling works phase effects is shown in Table 7.23.

Table 7.23: Summary of Enabling Works Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
River Hindburn (W478)	Very high	Increased fine sediment input	Temporary	Minor	Moderate - Significant
River Hodder (W477)	Medium	Increased fine sediment input	Temporary	Minor	Slight
		Changes to flow regime	Temporary	Minor	Slight
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Moderate	Moderate - Significant
Cod Gill (W206)	Medium	Changes to flow regime	Temporary	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Minor	Slight
Unnamed Watercourse 385 (W462)	Medium	Increased fine sediment input	Temporary	Negligible	Neutral
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Minor	Slight
		Disturbance of channel bed and banks	Temporary	Minor	Slight
Unnamed Watercourse 169 (W215)	Low	Increased fine sediment input	Temporary	Negligible	Neutral
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Negligible	Neutral
Unnamed Watercourse 384 (W461)	Low	Increased fine sediment input	Temporary	Negligible	Neutral
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Minor	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
		Dewatering	Temporary	Minor	Neutral
Unnamed Watercourse 386 (W463)	Low	Increased fine sediment input	Temporary	Negligible	Neutral
		Changes to flow regime	Temporary	Negligible	Neutral
		Loss of riparian vegetation	Long term	Negligible	Neutral
		Disturbance of channel bed and banks	Temporary	Minor	Neutral
Surface Water Quality					
River Hindburn (W478)	Very high	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
		Bank disturbance	Temporary	Negligible	Neutral
Cod Gill (W206) Unnamed Watercourse 169 (W215)	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
		Bank disturbance (only applies to W215)	Temporary	Minor	Slight
Watercourse 163 (W207)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
River Hodder (W477)	Very high	Sediment laden runoff	Temporary	Minor	Moderate - Significant
		Chemical pollution	Temporary	Negligible	Neutral
Unnamed Watercourse 384 (W461) Unnamed Watercourse 385 (W462)	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
		Bank disturbance	Temporary	Minor	Slight
Heaning Brook (W460)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Unnamed Watercourse 386 (W463) Unnamed Watercourse 1312 (W1382)	Low	Sediment laden runoff	Temporary	Minor	Neutral
		Chemical pollution	Temporary	Minor	Neutral
		Bank disturbance (only applies to W463)	Temporary	Minor	Neutral
Surface water habitat centred on NGR SD 68696 50425 (Lowland Fen)	Medium	Impacts to surface water habitat	Temporary	Moderate	Moderate - Significant
Groundwater					
Flow					
Superficial deposits aquifer – till (diamicton)	Medium	Localised drawdown of the water table around attenuation ponds	Temporary	Minor	Slight
		Migration of historic stockpile plume at Newton-in-Bowland Compound	Temporary	Minor	Slight
Secondary A bedrock aquifers	High	Localised drawdown of the water table around attenuation ponds	Temporary	Negligible	Neutral
		Migration of historic stockpile plume at Newton-in-Bowland Compound	Temporary	Minor	Slight
PWS3-16	Medium	Reduced flow capacity from dewatering	Temporary	Negligible	Neutral
		Reduced flow capacity from compaction	Temporary	Major	Large - Significant
PWS3-12	Medium	Reduced flow capacity from dewatering	Temporary	Negligible	Neutral
PWS3-8, PWS3-14 and PWS3-15	Medium	Reduced flow capacity from compaction	Temporary	Major	Large- Significant
Lunesdale North Well building	Medium	Ground settlement effects causing stability issues	Temporary	Minor	Slight
Watercourse 384	Low	Reduction in source availability due to dewatering	Temporary	Moderate	Slight

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Watercourse 384 and 385	Low	Reduced source availability due to compaction	Temporary	Negligible	Neutral
Lower House Cottage	Medium to low	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks	Temporary	Moderate	Moderate - Significant
Gamble Hole Farm Pasture	High	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks	Temporary	Major	Large
The Coach House	Medium	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks	Temporary	Moderate	Moderate – Significant
River Hodder North	Medium	Intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks	Temporary	Major	Large - Significant
Quality					
Superficial aquifer – glacial till (diamicton)	Medium	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Minor	Slight
Superficial aquifer – river terrace deposits	High	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Minor	Slight
Superficial aquifer – alluvium	High	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Minor	Slight
Secondary A bedrock aquifers	High	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Negligible	Neutral
PWS3-8, PWS3-14, PWS3-15	Medium	Changes to water quality due to ground disturbance from soil stripping and earthworks associated with access road and SuDS construction within the Newton-in-Bowland Compound	Temporary	Major	Large- Significant
		Changes to water quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Major	Large - Significant

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
PWS3-16	Medium	Changes to water quality due to ground disturbance from soil stripping and earthworks associated with the Lower Houses Compound	Temporary	Major	Large – Significant
		Changes to water quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Major	Large - Significant
PWS3-12	Medium	Changes to water quality due to ground disturbance from soil stripping and earthworks associated with SuDS construction at the Lower Houses Compound	Temporary	Negligible	Neutral
		Changes to water quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Minor	Slight
Gamble Hole Farm Pasture	High	Changes to groundwater quality due to ground disturbance from soil stripping and earthworks associated with Newton-in-Bowland Compound shaft	Temporary	Moderate	Moderate- Significant
	High	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Moderate	Moderate – Significant
River Hodder North	Medium	Changes to groundwater quality due to ground disturbance from soil stripping and earthworks associated with Newton-in-Bowland Compound shaft	Temporary	Moderate	Moderate – Significant
	Medium	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste	Temporary	Moderate	Moderate - Significant

7.6.2 Construction Phase

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

Fluvial Geomorphology

148) The construction phase of the Proposed Bowland 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 due to temporary culverts and bridges
- Fine sediment increases during the operation of access routes
- Surplus material storage
- Removal of temporary structures.

149) Without any specific mitigation , these activities would have the potential to cause the following effects:

- Changes to sediment regime
- Changes to flow regime
- Channel instability
- Dewatering.

Increased Fine Sediment Input

150) Whilst the access route at Lower Houses Compound would be in use, fine sediment could be mobilised and reach Unnamed Watercourse 169. Given the basic nature and limited range of geomorphological features and processes observed on this watercourse, it would be unlikely to be sensitive to changes in fine sediment input. Therefore, the impact on Unnamed Watercourse 169 due to increased supply of fine sediment would likely be negligible, with a neutral significance of effect.

151) Whilst the access route at Newton-in-Bowland Compound would be in use, fine sediment could be mobilised and reach the River Hodder. A range of geomorphological features and processes were observed on the River Hodder which would be sensitive to changes in sediment regime. However, the volumes of sediment mobilised are likely to be low. Therefore, the impact on this watercourse would likely be minor, with a slight significance of effect.

152) Whilst the access route at Newton-in-Bowland Compound would be in use, fine sediment could be mobilised and reach Unnamed Watercourse 385 and Unnamed Watercourse 386. Given the basic nature and limited range of geomorphological features and processes observed on these watercourses, they would be unlikely to be sensitive to changes in fine sediment input. Therefore, the impact on Unnamed Watercourse 385 and Unnamed Watercourse 386 would likely be negligible, with a neutral significance of effect.

153) Whilst the access route at Newton-in-Bowland Compound would be in use, fine sediment could be mobilised and reach Unnamed Watercourse 384. Given the basic nature and limited range of geomorphological features and processes observed on this watercourse, it would be unlikely to be sensitive to changes in fine sediment input. Therefore, the impact would likely be negligible, with a neutral significance of effect.

154) It would be proposed that surplus material would be stored within approximately 4 m of Unnamed Watercourse 384, representing a potential source of fine sediment which could be delivered to the watercourse. A limited range of geomorphological features and processes were observed on Unnamed Watercourse 384. However, the proximity of the material storage to the watercourse could result in significant volumes of fine sediment reaching Unnamed Watercourse 384, leading to aggradation and a change in-channel capacity. The impact would likely be moderate, with a slight significance of effect.

155) It would be proposed that surplus material would be stored within approximately 4 m of the surface water drainage infrastructure which discharges into Unnamed Watercourse 386, representing a potential source of fine sediment which could be delivered to the watercourse. Given the basic nature and limited range of geomorphological features and processes observed on this watercourse, it would be unlikely to be sensitive to changes in fine sediment input. Therefore, the impact on this watercourse would likely be negligible, with a neutral significance of effect.

156) It would be proposed that surplus material would be stored within approximately 35 m of the River Hodder on the valley sides of the watercourse, representing a potential source of fine sediment which could be delivered to the watercourse. In addition, there could be increased fine sediment supply from Unnamed Watercourse 384 and Unnamed Watercourse 386 (tributaries of the River Hodder). A range of geomorphological features and processes were observed on the River Hodder which would be sensitive to changes in fine sediment input. Therefore, the impact on this watercourse would likely be moderate, with a moderate significance of effect.

157) Unnamed Watercourse 384 and the River Hodder would be impacted by more than one new source of fine sediment during the construction phase of the Proposed Bowland Section. The most significant effect for both would likely be from the surplus material storage. Therefore, it is this source that has been used to determine an overall likely impact of moderate for both watercourses and a significance of effect slight and moderate for Unnamed Watercourse 384 and the River Hodder respectively. Unnamed Watercourse 386 would be impacted by two sources of fine sediment; both would have a negligible impact with a neutral significance of effect.

<u>Changes to Flow Regime</u>

158) Impacts associated with changes to flow regime are likely to be the same as those encountered during the enabling phase of the Proposed Bowland Section and are discussed in greater detail in Section 7.6.1.

<u>Channel Instability</u>

159) The River Hodder was seen to be laterally adjusting. Unsuitable reinstatement of bed and / or banks following the removal of the access route bridge and temporary outfalls could destabilise the reach 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.

160) Unnamed Watercourse 169 and Unnamed Watercourse 384 were seen to be stable during the site visit. The location of the temporary culvert on Unnamed Watercourse 386 was not visited during the site visit but this watercourse is also likely to be stable based on desk-study assessments. 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.

161) Unnamed Watercourse 385 exhibited evidence of actively incising. Unsuitable reinstatement of bed and / or banks following the removal of the temporary culvert could exacerbate this process and lead to channel instability 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.

162) 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.

<u>Dewatering</u>

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

Surface Water Quality

164) During the construction phase of the Proposed Bowland 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.

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

- Construction and sinking of two shafts and any (minimal) open-cut sections of tunnel that are required to link the Proposed Bowland Section to the existing aqueduct
- Reinstatement / demobilisation of construction site.

166) Without any specific mitigation , these activities during the construction works 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
- Bed and bank disturbance
- Impacts to surface water habitats.

Sediment Laden Runoff

167) The construction of two shafts, one located within each compound, 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 would be in use, there is the potential for silt laden runoff from these areas to reach identified receiving watercourses, which could lead to increases in suspended solids and turbidity.

168) As outlined in the enabling works phase, soil storage areas would be sited within an acceptable distance from any watercourses as defined in the CCoP. This distance would be large enough to ensure potential impacts from sediment laden runoff sourced from soil storage areas are minimised.

169) For the Lower Houses Compound and associated access route the outlined activities would have the potential to impact tributaries of the River Hindburn, Cod Gill and Unnamed Watercourse 169. Furthermore, site drainage would be discharged to Cod Gill from the Lower Houses Compound.

170) The Newton-in-Bowland Compound and its associated access route would have the potential to impact tributaries of the River Hodder: Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312. Furthermore, site drainage would be discharged to Unnamed Watercourse 384 from the Newton-in-Bowland Compound and the River Hodder via the existing Well House drain.

171) 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 is the potential for silt laden runoff to enter receiving watercourses, impacting on surface water quality.

172) Related to the Lower Houses Compound, the magnitude of impact of sediment laden runoff during the construction phase would be minor for Cod Gill and Unnamed Watercourse 169 and negligible for Unnamed Watercourse 163. This would result in a slight significance of effect for W206 (Cod Gill) and Unnamed Watercourse 169 and a neutral significance for Unnamed Watercourse 163.

173) All scoped-in watercourses that are at the north of the Proposed Bowland Section flow into the River Hindburn. The distance from the tributaries and dilution capacity of the tributaries and the River Hindburn would likely reduce the cumulative effect of sediment laden runoff to a negligible magnitude of impact, with a neutral significance of effect on the River Hindburn.

174) Related to the Newton-in-Bowland Compound, the magnitude of impact of sediment laden runoff during the construction phase would be minor for Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312 and negligible for Heaning Brook. This would result in a slight significance of effect for Unnamed Watercourse 384 and Unnamed Watercourse 385 and a neutral significance of effect for Unnamed Watercourse 386, Unnamed Watercourse 1312 and Heaning Brook.

175) All scoped-in watercourses at the south of the Proposed Bowland Section flow into the River Hodder. The River Hodder would have significant dilution capacity to mitigate / buffer against discharges it receives from site drainage; therefore, the effect of sediment laden runoff on the River Hodder would be anticipated to be negligible. This would result in a neutral significance of effect on the River Hodder.

Chemical Pollution

176) 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.

177) For the Lower Houses Compound and associated access routes this would have the potential to impact tributaries of the River Hindburn (Cod Gill and Unnamed Watercourse 169). For the Newton-in-Bowland Compound and associated access routes this would have the potential to impact tributaries of the River Hodder (Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312).

178) Similar to the assessment of potential sediment laden runoff impacts, the risks of chemical pollution affecting Unnamed Watercourse 163 and Heaning Brook would be anticipated to be reduced in comparison with other listed watercourses. This is due to their distance from, and proportion of site drainage they would receive, relative to both respective site compounds.

179) For watercourses associated with the Lower Houses Compound, the magnitude of impact of chemical pollution would be minor for Cod Gill and Unnamed Watercourse 169 and negligible for Unnamed Watercourse 163. This assumes that the CCoP (Appendix 3.2) would be adhered to including mitigation for chemical spills and fuel leaks. This would result in a slight significance of effect for Cod Gill and Unnamed Watercourse 169 and a neutral significance of effect for Unnamed Watercourse 163.

180) All scoped-in watercourses north of the Proposed Bowland Section flow into the River Hindburn. Given the overall distance and dilution capacity of the tributaries and the River Hindburn, the cumulative effect of chemical pollution would likely have a negligible magnitude of impact, resulting in a neutral significance of effect on the River Hindburn.

181) Related to the Newton-in-Bowland Compound, the magnitude of impact of chemical pollution, during the construction phase, would be minor for Unnamed Watercourse 384, Unnamed Watercourse 385, Unnamed Watercourse 386 and Unnamed Watercourse 1312 and negligible for Heaning Brook. This would result in a slight significance of effect for Unnamed Watercourse 384 and Unnamed Watercourse 385 and a neutral significance of effect for Unnamed Watercourse 386, Unnamed Watercourse 1312 and Heaning Brook.

182) All scoped-in watercourses associated with the southern Newton-in-Bowland Compound flow into the River Hodder. The River Hodder would have significant dilution capacity to mitigate / buffer against chemical pollution discharges into the river; therefore, the impact of chemical pollution on the River Hodder is reported as negligible. This results in a neutral significance of effect on the River Hodder.

Bed and Bank Disturbance

183) The culverts would be in use throughout the construction phase and could 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 would not directly link to a specific construction activity but are rather symptoms of them.

184) 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 could increase turbidity and suspended solids decreasing water quality. It would be anticipated the channel bed would be restored to baseline conditions.

185) 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 during construction would be minor for Unnamed Watercourse 169. This would result in a slight significance of effect for this watercourse.

186) For the four culvert crossings associated with the Newton-in-Bowland Compound, the magnitude of impact would be minor for Unnamed Watercourse 384, Unnamed Watercourse 385 and Unnamed Watercourse 386. This would result in a slight significance of effect for Unnamed Watercourse 384 and Unnamed Watercourse 385 and a neutral significance of effect for Unnamed Watercourse 386.

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

Impacts to Surface Water Habitats

188) The same potential impacts to the area of Lowland Fen would be present during the construction phase as reported in the enabling works phase. As a result of the potential impacts outlined previously, the magnitude of impact on the area of Lowland Fen would be anticipated to be moderate resulting in a significance of effect of moderate.

Groundwater

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

Groundwater Flow

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

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

Shaft and Portal Construction

191) Given the proposed design activities related to installing the 15 m diameter launch and reception shaft structure at the Lower Houses Compound shaft to a depth of 10.5 mbgl and Newton-in-Bowland portal at 11 mbgl, there would be associated potential impacts due to dewatering of the surrounding aquifer during shaft and portal construction. The dewatering impact would apply only during shaft and portal construction, with the shaft being fully sealed prior to the commencement of tunnelling.

192) Construction of the Lower Houses Compound shaft and Newton-in-Bowland portal would be expected to impact groundwater in superficial till deposits (medium sensitivity) and underlying bedrock (high sensitivity).

193) The Sichardt method (e.g. Preene *et al.*, 2016)[22] was used to estimate the dewatering zone of influence around the Lower Houses Compound shaft and Newton-in-Bowland portal, each expected to intercept groundwater. This was applied using the estimated drawdown of groundwater levels to the base of the excavations during construction. For the shaft, the estimation accounts 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 for each excavation calculation were obtained from generic values from the scientific literature (Domenico and Schwartz, 1990)[23] appropriate to the materials recorded during the GI where in-situ testing was not available. In this case, permeability tests (e.g. packer tests) were not conducted in boreholes in the vicinity of the proposed excavation areas during the GI at the required depths for shaft and portal assessment (see Table 7.15).

194) The zone of influence for the shaft estimated using the Sichardt method was quite small. The Sichardt method is considered to be unreliable for small values of the zone of influence. Therefore, in order to ensure a suitable conservative assessment, a minimum zone of influence of 25 m has been assumed and was applied for the Lower Houses shaft excavation in this case. The calculated radius of influence for the Newton-in-Bowland portal is 73 m. These together would generate a localised impact on till at Lower Houses and Newton-in-Bowland compounds, considered to be a minor magnitude at the scale of the superficial aquifer. Despite the excavation depths for the shaft and portal, considering the larger scale of the bedrock aquifer, the potential impact is considered to be a minor magnitude. Therefore, the resulting potential significance of effect would be slight on superficial and bedrock aquifers.

195) Three PWS, PWS3-13, PWS3-14, and PWS3-15, described as springs, would be potentially impacted by dewatering. They are located some distance downgradient of groundwater flow from the Newton-in-Bowland portal excavation and outside of the calculated zone of influence of drawdown. However, given the proximity and location downgradient, the effects of groundwater drawdown could cause a reduction in capacity at each of the supplies. For supplies PWS3-14 and PWS3-15 (Fober Farm supply), located some 110 m from the portal excavation, the potential magnitude of impact is considered to be minor. For PWS3-13 (Gamble Hole Farm supply), at approximately 200 m from the portal, the potential magnitude of impact is considered to be negligible. Therefore, the potential significance of effect from the construction of the portal would be slight for PWS3-14 and PWS3-15 and neutral for PWS3-13.

196) At the Lower Houses Compound, PWS3-16 is the closest PWS, located approximately 200 m downgradient of the shaft and out of range of the radius of influence of drawdown. As a result, the potential magnitude of impact is considered to be negligible. Therefore, the potential significance of effect from the construction of the shaft would be neutral.

197) Unnamed Watercourse 385 (medium sensitivity) would be expected to be impacted by dewatering activities associated with the Newton-in-Bowland portal. Despite being outside of the calculated zone of influence of groundwater drawdown, the watercourse is located downgradient of dewatering, which would result in a localised, small-scale reduction in resource availability categorised as a moderate magnitude impact. The potential significance of effect for the portal on the nearby watercourse is therefore assessed as moderate.

198) Groundwater dewatering can cause differential settlement effects on existing infrastructure and buildings. One existing small building (medium sensitivity), located at the edge of the radius of influence of drawdown south-east of the Newton-in-Bowland portal, could be expected to be impacted during this phase of works. However, due to the localised dewatering required for this construction, the magnitude of impact would be categorised as minor, resulting in a potential significance of effect of slight. No other properties, listing buildings, scheduled monuments or infrastructure would be expected to be impacted from construction of the Newton-in-Bowland portal.

199) Impacts due to shaft and portal construction and dewatering on groundwater flows supporting GWDTEs are summarised in Table 7.24. A detailed description of potential impacts on groundwater levels and flows at all sites in the refined GWDTE assessment area is provided in Appendix 7.2.

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

Table 7.24: Summary of Potential Significant Effects on GWDTEs Groundwater Flows

Site Name	Sensitivity	Activity / Effect	Magnitude of Impact	Significance of Effect
Gamble Hole Farm Pasture	High	Newton-in-Bowland portal dewatering (groundwater levels / flows)	Major	Very large - Significant

200) At the Lower Houses shaft, no properties, listed buildings, scheduled monuments or infrastructure have been identified within the potential zone of influence of dewatering. Equally, no groundwater abstraction, no surface water feature, no GWDTE and no contaminated land is located within the zone of influence of the shaft.

Tunnel Construction

201) The tunnel would be formed using a tunnel boring machine, with the tunnel continuously lined as boring progresses. Daily progress would be expected to average approximatively 10 m per day, with a maximum of 10 m of open head (unlined) bedrock. Additional details on the proposed drilling methodology, including embedded measures to control groundwater pressures, are included in Appendix 7.8. Initial dewatering volume estimates were produced by United Utilities[24] using parameters based on the anticipated construction method. The modelled average inflow for the Proposed Bowland Section was 1.55 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).

202) Given the above, groundwater disturbances within bedrock are expected to be minor and localised and short-lived. As a result, any groundwater flow disturbance is expected to be negligible at the scale of the aquifer, resulting in a potential significance of effect of neutral.

203) PWS3-7, which is described as a borehole, is located approximatively 100 m from the tunnel (and roughly 220 m downgradient with respect to groundwater flow direction). The exact source location and depth of this supply has not been verified and could be further upgradient, closer to the tunnel . Given the depth of the tunnel at this location (approximatively 60 m) no impact would be expected on PWS3-7.

204) Similarly, given the depth of tunnel, no impact would be expected to surface receptors such as surface waters and GWDTEs.

Other Flow Disruption Impacts

205) The other works that would be expected to involve excavation of the ground surface during the construction phase are the single and multi-line connection constructions, connecting to the existing aqueduct at either end of the Proposed Bowland Section tunnel, both at Lower Houses Compound and Newton-in-Bowland Compound areas, and the excavation for overflow at Newton-in-Bowland 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.

206) As discussed in the enabling stage, there is uncertainty on groundwater levels in superficial deposits and bedrock in the vicinity of the Lower Houses Compound and Newton-in-Bowland Compound from the initial draft GI data, and a conservative groundwater level of 1 m below ground was assumed present in superficial till deposits (medium sensitivity). Dewatering of all excavations would therefore be expected to generate a localised minor potential impact, resulting in a potential significance of effect of slight on groundwater superficial deposit aquifers.

207) The excavations could reach the top of the bedrock and intercept groundwater at the levels recorded in bedrock. The magnitude of impact would be considered minor, given the scale of the bedrock aquifers, resulting in a potential significance of effect of slight.

[24] United Utilities (2020). Dewatering Volume estimates. Document Ref.: 80061155-01-UU-MISCE-XX-DC-C-00004.xlsx.

208) The Sichardt method (e.g. Preene et al., 2016)[25] 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 for each excavation calculation were obtained from generic values from the scientific literature (Domenico and Schwartz, 1990)[26] appropriate to the materials recorded during the GI where in-situ testing was not available. In this case, permeability tests (e.g. packer tests) were not conducted in boreholes in the vicinity of the proposed excavation areas during the GI at the required depths for shaft and portal assessment (see Table 7 15).

209) 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 would be assumed and was applied for connection and overflow excavations at Lower Houses Compound and Newton-in-Bowland Compound areas in this case.

210) 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 7.6, conducted using calculated zones of influence for each feature. The review is based on the understanding of geology and water-level data from the initial draft GI data.

211) PWS3-8, which is described as a spring, could be directly impacted by the connection open-cut excavations at the Newton-in-Bowland Compound. In addition, the nature of abstraction and its location would need to be confirmed on site. As shown in Appendix 7.6, this could result in a potential significance of effect of large as a result of associated dewatering activities.

212) PWS3-14 and PWS3-15 (Fober Farm supply) are located approximately 100 m and 30 m downgradient of the connection and overflow open-cut excavations respectively at Newton-in-Bowland. These are understood to be spring-fed supplies. As a result, despite being out of range of the calculated radius of influence, their position downgradient of groundwater flow means that they would each be considered to be potentially impacted from drawdown. As shown in Appendix 7.6, this could result in a potential significance of effect of moderate as a result of associated dewatering activities.

213) PWS3-12 and PWS3-16 are located approximately 200 m downgradient of the proposed open-cut excavation to install the connection to the existing aqueduct. PWS3-12 is expected to be sourced from a borehole, albeit its exact location and depth have not been confirmed and the supply type for PWS3-16 is unknown. Potential flow impacts on these supplies are unlikely; however, given the remaining uncertainties, as shown in Appendix 7.6, this could result in a potential significance of effect of neutral as a result of associated dewatering activities.

214) Three surface watercourses have been identified that are considered to be potentially impacted by dewatering. Cod Gill watercourse (medium sensitivity) lies within the zone of influence of groundwater drawdown for the Lower Houses Compound connection excavation as shown in Appendix 7.6. Therefore, a potential reduced contribution to baseflow is expected, assessed as minor magnitude, resulting in a potential significance of effect of slight.

215) Unnamed Watercourse 384 and Unnamed Watercourse 385 (both of low sensitivity) have been identified as potentially in range of dewatering activities at Newton-in-Bowland Compound, as they lie downgradient of groundwater flow from connection and overflow open-cut excavations. However, as described in Appendix 7.6, it would be expected that the abstracted water would be returned to the watercourses immediately downgradient of the works and, consequently, the resulting potential significance of effect is assessed as slight.

216) Groundwater dewatering can cause differential settlement effects on existing infrastructure and buildings. For the Proposed Bowland Section, four existing buildings (each of medium sensitivity) have been identified within range of dewatering. Three of which, including the Hodder North Well building, exist within the Newton-in-Bowland Compound, within zones of influence of groundwater drawdown at the connection and overflow open-cut excavations. As shown in Appendix 7.6, each would be expected

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

to be impacted during this phase of works and, due to the small-scale, localised dewatering proposed at the excavation areas, would be categorised as a minor magnitude of impact, resulting in a potential significance of effect of slight.

217) One small building is identified as potentially within range of dewatering activities associated with the construction of the open-cut Lower Houses Compound connection excavation. As shown in Appendix 7.6, due to the small-scale, localised dewatering required for this construction, it would be categorised as a minor magnitude of impact, resulting in a potential significance of effect of slight.

218) No impacts to licensed abstractions, other properties, listed buildings, cultural heritage sites, scheduled monuments or infrastructure would be expected to be impacted from the connection and overflow excavations at the Lower Houses and Newton-in-Bowland compounds.

219) Potential significant effects due to overflow and connection construction on groundwater flows supporting GWDTEs are summarised in Table 7.25. All potential impacts on groundwater levels and flows in the refined GWDTE assessment area are discussed in detail in Appendix 7.2.

Table 7.25: Summary of Significant Effects to GWDTEs

Site Name	Sensitivity	Activity / Effect	Magnitude of Impact	Significance of Effect
Gamble Hole Farm Pasture	High	Newton-in-Bowland Compound open-cut connection dewatering (groundwater levels / flows)	Major	Large - Significant

Groundwater Quality

220) 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 the sub-soil and affect adjacent sensitive receptors (e.g. shallow groundwater abstractions and GWDTEs).

221) Taking into account the CCoP (Appendix 3.2) which already refers to 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 7.26.

Table 7.26: Potential Impact of Ground Disturbance from Earthworks on Key Hydrogeological Receptors

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
Spring, PWS3-8	Medium	Major	Within compound and potentially present within the footprint of the connection and overflow works at Newton-in-Bowland Compound.	Large – Significant
PWS3-14 and PWS3-15	Medium	Moderate	Within compound and downgradient of the portal, connection and overflow works at the Newton-in-Bowland Compound.	Moderate – Significant
PWS3-16	Medium	Moderate	Within compound and downgradient of the shaft and connection excavation works at the Lower Houses Compound.	Moderate – Significant
PWS3-13	Medium	Negligible	Located some 200 m downgradient from nearest excavation works at Newton-in-Bowland Compound during the construction phase.	Neutral

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
PWS3-12	Medium	Negligible	Located some 215 m downgradient from nearest excavation works at Lower Houses Compound during the construction phase.	Neutral
No impact to other PWS or licensed abstractions would be expected.				
Gamble Hole Farm Pasture	High	Moderate	Present within the Newton-in-Bowland Compound. Embedded mitigation and good practice measures 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
River Hodder North	Medium	Minor	Present within the Newton-in-Bowland Compound access track area. Embedded mitigation and good practice measures 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.	Slight
All other GWDTEs are expected to receive effects with a slight or neutral significance of effect or receive no impacts.				

222) 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.

223) 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 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 7.27 taking into account the embedded measures recorded in the CCoP (Appendix 3.2).

Table 7.27: Potential Impact of Accidental Spillages on Key Hydrogeological Receptors

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
Superficial aquifer – glacial till (diamicton)	Medium	Minor	Present across each site operational during construction, i.e. the Lower Houses Compound and Newton-in-Bowland Compound.	Slight
Secondary A bedrock aquifers	High	Minor	Present at Lower Houses Compound and Newton-in-Bowland Compound where excavations are proposed at depths reaching bedrock.	Slight
PWS3-8	Medium	Major	Present within the Newton-in-Bowland Compound in close proximity to open-cut excavation works.	Large – Significant

Groundwater Receptors	Sensitivity	Magnitude of Impact	Additional Comments	Significance of Effect
PWS3-14, PWS3-15 (Fober Farm supply)	Medium	Moderate	Present within the Newton-in-Bowland Compound downgradient of excavation works.	Moderate – Significant
PWS3-16	Medium	Moderate	Present within the Lower Houses Compound downgradient of excavation works.	Moderate – Significant
PWS3-12	Medium	Negligible	Present some 160 m downgradient from the Lower Houses Compound.	Neutral
PWS3-13 (Gamble Hole Farm supply)	Medium	Negligible	Present some 115 m downgradient from the Newton-in-Bowland Compound.	Neutral
All other PWS are not considered to be impacted during the construction phase of works.				
Gamble Hole Farm Pasture	High	Moderate	Present within the Newton-in-Bowland Compound. Embedded mitigation and good practice measures 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
River Hodder North	Medium	Minor	Present within the Newton-in-Bowland Compound access track area. Embedded mitigation and good practice measures 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.	Slight
All other GWDTEs are expected to receive effects with a slight or neutral significance of effect or receive no impacts.				

224) The desk-based investigations have identified areas of disturbed ground, some associated with the construction of the original / existing Haweswater Aqueduct, which for the purposes of a reasonable worst case assessment are assumed to be potentially contaminated. These comprise a historical stockpile located close to the centre of the compound, an infilled historical limestone quarry to the east of the proposed portal excavation, and a historic valve house due east of, and in close proximity to, the connection and overflow excavations. The desk study for this section[27] indicates possible contaminants associated with the historical stockpile as: metals, inorganic compounds, hydrocarbon fuels / oils, and asbestos. No further information was available on the potential nature of the contamination associated with these sites.

225) The historical stockpile is positioned some 100 m south of the Newton-in-Bowland portal, outside of the zone of influence of groundwater dewatering, cross-gradient of groundwater flow. The excavations for connection and overflow lie within the mapped footprint of the historical stockpile and downgradient from the historical quarry. The potential magnitude of impact to the underlying superficial (medium sensitivity) and bedrock (high sensitivity) aquifers would be considered negligible due to the relative size of the aquifer, resulting in a potential significance of effect of neutral on both superficial and bedrock aquifers.

[27] United Utilities (2020) *Geotechnical and Geoenvironmental Desk Study Report: Haweswater Aqueduct Resilience Programme: TR3 Option 2*.

226) The mobilisation of any contaminated groundwater plume associated with the known contaminated land sites discussed above could also affect the catchment area of PWS3-8 (spring source). PWS3-8 is located within the mapped footprint of the historical stockpile and downgradient from the historical quarry; however, it is not known if there is any existing effect on this source and it has been assumed to be currently unaffected for the purpose of this assessment. Due to its proximity to the potential zone of plume migration, a potential change to water quality of the supply would be expected. The potential impact is considered to be a moderate magnitude, resulting in a potential significance of effect of moderate.

227) The historic limestone quarry site is positioned at the edge of the zone of influence of groundwater drawdown for the proposed portal works and is expected to be upgradient of groundwater flow. This would be considered to cause minor, temporary changes to groundwater quality to superficial (medium sensitivity) and bedrock (high sensitivity) aquifers which would be categorised as a negligible magnitude impact, resulting in a neutral potential significance of effect to both superficial and bedrock aquifers.

228) The site of the historical valve house falls within the dewatering zone of influence for the Newton-in-Bowland connection and overflow excavation works. The potential magnitude of impact to the underlying superficial (medium sensitivity) and bedrock (high sensitivity) aquifers would be considered negligible due to the relative size of the aquifer, resulting in a potential significance of effect of neutral on both superficial and bedrock aquifers.

229) A historic stockpile has been identified close to the Lower Houses Compound, some 200 m from the shaft, which could be a potential source of contaminants. PWS3-16 is located downgradient, within 200 m from both, and could become contaminated from the stockpile plume. As the stockpile is well outside of the radius of influence for shaft dewatering, it is considered unlikely that the stockpile plume would migrate towards the shaft excavation to be within range of the supply. As a result, any impact from shaft dewatering is considered to be negligible, resulting in a potential significance of effect of neutral for PWS3-16.

Summary of Effects

230) A summary of the construction phase effects is shown in Table 7.28.

Table 7.28: Summary of Construction Phase Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
River Hodder (W477)	Medium	Increased fine sediment input	Temporary	Moderate	Moderate – Significant
		Changes to flow regime	Temporary	Moderate	Moderate – Significant
		Channel instability	Long term	Moderate	Moderate – Significant
Cod Gill (W206)	Medium	Changes to flow regime	Temporary	Negligible	Neutral
Unnamed Watercourse 385 (W462)	Medium	Increased fine sediment input	Temporary	Negligible	Neutral
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Moderate	Moderate – Significant
Unnamed Watercourse 384 (W461)	Low	Increased fine sediment input	Temporary	Moderate	Slight
		Changes to flow regime	Temporary	Minor	Neutral
		Channel instability	Long term	Minor	Neutral
Unnamed Watercourse 169 (W215)	Low	Increased fine sediment input	Temporary	Negligible	Neutral
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Negligible	Neutral
Unnamed Watercourse 386 (W463)	Low	Increased fine sediment input	Temporary	Negligible	Neutral
		Changes to flow regime	Temporary	Negligible	Neutral
		Channel instability	Long term	Negligible	Neutral
Surface Water Quality					
River Hindburn (W478)	Very high	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
		Bank disturbance	Temporary	Negligible	Neutral
Cod Gill (W206) Unnamed Watercourse 169 (W215)	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
		Bank disturbance (only applies to W215)	Temporary	Minor	Slight
Unnamed Watercourse 163 (W207)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
River Hodder (W477)	Very high	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Unnamed Watercourse 384 (W461) Unnamed Watercourse 385 (W462)	Medium	Sediment laden runoff	Temporary	Minor	Slight
		Chemical pollution	Temporary	Minor	Slight
		Bank disturbance	Temporary	Minor	Slight
Heaning Brook (W460)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Unnamed Watercourse 386 (W463) Unnamed Watercourse 1312 (W1382)	Low	Sediment laden runoff	Temporary	Minor	Neutral
		Chemical pollution	Temporary	Minor	Neutral
		Bank disturbance (only applies to W463)	Temporary	Minor	Neutral
Surface water habitat centred on NGR SD 68696 50425 (Lowland Fen)	Medium	Impacts to surface water dependent habitat.	Temporary	Moderate	Moderate – Significant
Groundwater					
Flow					
Superficial aquifer – glacial till (diamicton)	Medium	Localised drawdown of the water table around the shaft / portal, connection and overflow excavations at Lower	Temporary	Minor	Slight

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
		Houses Compound and Newton-in-Bowland Compound.			
Secondary A bedrock aquifers	High	Localised drawdown of the water table around shaft / portal excavations at Lower Houses Compound and Newton-in-Bowland Compound.	Temporary	Minor	Slight
		Localised drawdown of the water table around connection and overflow excavations at Lower Houses Compound and Newton-in-Bowland Compound.	Temporary	Minor	Slight
		Disturbance to groundwater flow from the construction of the tunnel.	Temporary	Negligible	Neutral
Spring PWS3-14	Medium	Reduced capacity due to dewatering at connection and overflow excavations at the Newton-in-Bowland Compound.	Temporary	Moderate	Moderate – Significant
		Reduced capacity due to dewatering at portal excavation at the Newton-in-Bowland Compound.	Temporary	Minor	Slight
Spring PWS3-15	Medium	Reduced capacity due to dewatering at connection and overflow excavations at the Newton-in-Bowland Compound.	Temporary	Moderate	Moderate – Significant
		Reduced capacity due to dewatering at portal excavation at the Newton-in-Bowland Compound.	Temporary	Minor	Slight
PWS3-16	Medium	Reduced capacity due to dewatering at the shaft and connection excavation at the Lower Houses Compound.	Temporary	Negligible	Neutral
PWS3-12	Medium	Reduced capacity due to dewatering at connection and overflow excavations at the Lower Houses Compound.	Temporary	Negligible	Neutral
PWS3-13	Medium	Reduced capacity due to dewatering at the Newton-in-Bowland portal.	Temporary	Negligible	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
PWS3-8	Medium	Reduced capacity due to dewatering at connection and overflow excavations at the Newton-in-Bowland Compound.	Permanent	Major	Large – Significant
Surface water feature – Cod Gill Watercourse	Medium	Reduced contribution to baseflow from dewatering activities at the Lower Houses Compound connection excavation.	Temporary	Minor	Slight
Surface water feature – Unnamed Watercourse 385	Medium	Reduced contribution to baseflow from dewatering activities at the portal, connection and overflow excavations at the Newton-in-Bowland Compound.	Temporary	Moderate	Moderate – Significant
Surface water feature – Unnamed Watercourse 384	Low	Reduced contribution to baseflow from dewatering activities at the connection and overflow excavations at the Newton-in-Bowland Compound.	Temporary	Minor	Slight
Existing small building at the Lower Houses Compound	Medium	Subsidence induced by dewatering.	Temporary	Minor	Slight
Three existing small buildings including Hodder North Well building located within the Newton-in Bowland Compound	Medium	Subsidence induced by dewatering.	Temporary	Minor	Slight
Gamble Hole Farm Pasture	High	Localised drawdown of the water table around the Newton-in-Bowland portal and disturbances to groundwater flows.	Temporary	Major	Very large – Significant
		Localised drawdown of the water table around the Newton-in-Bowland open-cut connection and disturbances to groundwater flows.	Temporary	Major	Large – Significant
Quality					
Superficial aquifer – glacial till (diamicton)	Medium	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste at Lower Houses Compound and Newton-in-Bowland Compound.	Temporary	Minor	Slight

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
		Existing contaminant plume migration	Temporary	Negligible	Neutral
Secondary A bedrock aquifers	High	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste at Lower Houses Compound and Newton-in-Bowland Compound.	Temporary	Minor	Slight
		Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste at the Newton-in-Bowland access track.	Temporary	Negligible	Neutral
		Existing contaminant plume migration	Temporary	Negligible	Neutral
Spring PWS3-14	Medium	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Moderate	Moderate – Significant
		Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Moderate	Moderate – Significant
PWS3-16	Medium	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Moderate	Moderate – Significant
		Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Moderate	Moderate – Significant
		Contamination from mobilisation of a groundwater plume associated with a historic stockpile at the Lower Houses Compound.	Temporary	Negligible	Neutral
PWS Spring PWS3-15	Medium	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Moderate	Moderate – Significant
		Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Moderate	Moderate – Significant

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
		Contamination from mobilisation of a groundwater plume associated with a historic stockpile at the Newton-in-Bowland Compound.	Temporary	Moderate	Moderate – Significant
PWS3-12	Medium	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Negligible	Neutral
		Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Negligible	Neutral
PWS3-13	Medium	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Negligible	Neutral
		Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Negligible	Neutral
PWS3-8	Medium	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Major	Large – Significant
		Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Major	Large – Significant
		Contamination from mobilisation of groundwater plumes associated with a historical quarry and historical stockpile at the Newton-in-Bowland Compound.	Temporary	Moderate	Moderate – Significant
Gamble Hole Farm Pasture	High	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Moderate	Moderate – Significant
	High	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Moderate	Moderate – Significant

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
River Hodder North	Medium	Changes to groundwater quality due to mobilisation of soil and rock particles from ground disturbance.	Temporary	Minor	Slight
	Medium	Changes to groundwater quality due to accidental spillages from fuel storage and storage of materials and waste.	Temporary	Minor	Slight

7.6.3 Commissioning Phase

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

Fluvial Geomorphology

232) During the commissioning phase of the Proposed Bowland Section there would be a discharge of commissioning water flows from the proposed aqueduct.

233) Without any specific mitigation, this activity would have the potential to cause changes to the flow and sediment transport regimes, which has been described in more detail below.

Changes to Flow and Sediment Transport Regimes

234) At the north end of the Proposed Bowland Section, commissioning flows would discharge into Cod Gill. This would be through the temporary outfall used for construction drainage and surface water runoff from Lower Houses Compound at a rate of 25 l/s. This is likely to be higher than the existing flows in Cod Gill. Although the location of the outfall was not visited, analysis of aerial photographs suggests erosion is occurring at this location which would likely be exacerbated by changes in the local flow regime. 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, there would likely be a moderate magnitude of impact on the watercourse with a moderate significance of effect.

235) Cod Gill is a tributary of the River Hindburn. The increase in flow in Cod Gill due to the commissioning flows is likely to affect flows on the River Hindburn and could cause localised erosion at the confluence. In addition, the anticipated increase in fine sediment load mobilised on Cod Gill could smother the highly sensitive morphological features observed on the River Hindburn. Therefore, the commissioning flows would likely have a moderate magnitude of impact on the watercourse with a large significance of effect.

236) At the south end of the Proposed Bowland Section, commissioning flows would discharge into the River Hodder. This would be through the existing overflow structure at a rate of 25 l/s.

237) Table 7.29 shows that the commissioning flow would not have a significant impact on the specific stream power of the River Hodder and suggests the commissioning flow rate is within the range of flows already experienced by the River Hodder. For context, a river with a specific stream power of less than 10 Watts per metre squared (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 River Hodder, 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.

238) Additional analysis of the sediment entrainment capabilities of the River Hodder show that there would be no change in the grain size of sediment transported during the discharge of commissioning flows. Consequently, there would likely be little change in the baseline geomorphological processes and features as a result of the commissioning flows from the existing aqueduct. This has been assessed to have a negligible magnitude of impact on the River Hodder with a neutral significance of effect.

Table 7.29: River Hodder Specific Stream Power

Flow Percentile	Specific Stream Power - ω (W/m^2)	
	Baseline	Commissioning Phase
Q95	1.5	1.8
Q50	5.2	5.6
Qmed (bankfull)	215	215.4

Surface Water Quality

239) During the commissioning phase of the Proposed Bowland 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.

240) Without any specific 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>

241) As part of the commissioning works there would be a requirement for the transfer of chlorinated water from the existing aqueduct through a de-chlorination plant to two or more attenuation ponds prior to discharge to surface water receptors. The commissioning flows would be transferred between the existing aqueduct and attenuation without any leakage, which 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 Cod Gill and River Hodder.

242) Furthermore, it is assumed the attenuation ponds would be sized appropriately 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 for a short duration in Cod Gill, and to a lesser extent the River Hindburn following dilution capacity. At the southern end of the Proposed Bowland Section there would be the potential for the water quality of River Hodder to be affected.

243) As a result, the magnitude of impact would be minor for Cod Gill and, due to the combined dilution factor and overall distance from the discharge location, the magnitude of impact would be negligible for the River Hindburn for the discharge of untreated commissioning discharges. This would result in a slight significance of effect for Cod Gill and a neutral significance of effect for the River Hindburn. For River Hodder the magnitude of impact would be negligible, which would result in a neutral significance of effect.

<u>Bank Disturbance</u>

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

245) 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 Cod Gill would be minor, which results in a slight significance of effect for this watercourse. As a consequence of the catchment connectivity and dilution factors associated with the River Hindburn the magnitude of impact for the River Hindburn is reported as negligible, which results in a neutral significance of effect.

246) At the southern end of the Proposed Bowland Section the commissioning flows would be discharged to the River Hodder. The rate of discharge is likely to be in the range of flows experienced by the River Hodder and therefore the impact that could be caused by short-term bank disturbance with associated

impacts on water quality is likely to be low. The magnitude of impact on water quality to the River Hodder is reported as negligible, which results in a neutral significance of effect for this watercourse.

Groundwater

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

Summary of Effects

248) A summary of the commissioning phase effects is shown in Table 7.30.

Table 7.30: Summary of Commissioning Phase Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
River Hindburn (W478)	Very high	Changes to flow and sediment transport regimes	Temporary	Moderate	Large – Significant
River Hodder (W477)	Medium	Changes to flow and sediment transport regimes	Temporary	Negligible	Neutral
Cod Gill (W206)	Medium	Changes to flow and sediment transport regimes	Temporary	Moderate	Moderate – Significant
Surface Water Quality					
River Hindburn (W478)	Very high	Discharge of untreated commission flows	Temporary	Negligible	Neutral
		Bank disturbance	Temporary	Negligible	Neutral
Cod Gill (W206)	Medium	Discharge of untreated commission flows	Temporary	Minor	Neutral
		Bank disturbance	Temporary	Minor	Neutral
River Hodder (W477)	Very high	Discharge of untreated commission flows	Temporary	Negligible	Neutral
		Bank disturbance	Temporary	Negligible	Neutral

7.6.4 Operational Phase

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

Fluvial Geomorphology

250) During the operational phase of the Proposed Bowland Section there would be discharge of flows from the proposed aqueduct.

251) Without any specific mitigation , this activity would have the potential to change the flow regimes, which has been described in more detail below.

<u>Changes to Flow Regime</u>

252) The overflow from the Proposed Bowland Section aqueduct would discharge at the existing outfall location on the River Hodder. 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 Bowland Section. Therefore, there would be no change from baseline condition, and the impact would likely be negligible with neutral significance of effect.

Surface Water Quality

253) The operational phase of the Proposed Bowland 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 (oils, fuels and chemicals)
- Operational discharges.

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

- Sediment laden runoff
- Chemical pollution
- Localised erosion changing water quality.

<u>Sediment Laden Runoff</u>

255) A permanent access track to the north end of the Proposed Bowland Section would be required for access to the new well house. The access route would make use of an existing access track (near Lower House Cottage) which crosses Cod Gill. Provided that this access track would not need to be upgraded or widened there would be no change from baseline conditions. Therefore, the magnitude of impact on Cod Gill and the River Hindburn would be negligible, resulting in a neutral significance of effect for both watercourses. It is assumed that the northern access track use extending from Park House Lane during the enabling and construction phases would be reinstated prior to the operational phase and therefore no impacts from this access track are anticipated.

256) At the south end of the Proposed Bowland Section, there would be a permanent access route to the two new well houses. It is anticipated that the access route would make use of an existing access track and, providing it would not need to be upgraded or widened, there would be no change from baseline conditions. Therefore, the magnitude impact on (the nearest draining watercourse) Unnamed Watercourse 384 and the River Hodder would be negligible, with a neutral significance of effect for both watercourses.

Chemical Pollution

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

258) The magnitude of impact on surface water quality from chemical pollution during the operational phase at the north end of the Proposed Bowland Section for Cod Gill and the River Hindburn would be negligible resulting in a neutral significance of effect for both watercourses.

259) The magnitude of impact on surface water quality from chemical pollution during the operational phase at the southern end of the Proposed Bowland Section for Unnamed Watercourse 384 and the River Hodder would be negligible resulting in a neutral significance of effect for both watercourses.

Localised Erosion Changing Water Quality

260) The overflow from the Proposed Bowland Section aqueduct would discharge at the existing outfall on River Hodder. 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 may have the potential to cause local erosion issues which may lead to increased turbidity downstream of the outfall location on the River Hodder. Due to the limited number and time period between operational discharges on the Proposed Bowland Section aqueduct, the magnitude of impact on the River Hodder is reported as negligible, resulting in a **neutral** significance of effect.

Groundwater

261) No groundwater dewatering would be required during the operational phase; therefore, no impact to groundwater flow from dewatering has been assessed.

Permanent Shaft Structure on Groundwater Flows

262) Given the proposed shaft design diameter (15 m) and depth (10.5 mbgl) of the Lower Houses Compound shaft, long-term groundwater disturbances would be expected to be negligible. As a result, any impact would be expected to be negligible for both superficial and bedrock aquifers, resulting in a potential significance of effect for both of neutral.

263) The anticipated situation at the Newton-in-Bowland compound, however, is different. Potential significant effects due to permanent below-ground structures on groundwater flows supporting GWDTEs are summarised in Table 7.31. A detailed description of the potential impact assessment for all GWDTEs in the refined GWDTE assessment area is provided in Appendix 7.2.

Table 7.31: Summary of Significant Effects to GWDTEs

Site Name	Sensitivity	Activity / Effect	Magnitude of Impact	Significance of Effect
Gamble Hole Farm Pasture	High	Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Moderate	Moderate – Significant

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

Permanent Tunnel Structure on Groundwater Flows

265) Given the Proposed Bowland Section tunnel design depth and dimensions (diameter of 3.5 m) and that the tunnel would be sealed, groundwater disturbances would be expected to be negligible at the scale of the bedrock aquifer, resulting in a potential neutral significance of effect.

266) Two PWS are located in proximity to the Proposed Bowland Section tunnel. PWS3-7 is located approximately 100 m from the tunnel, or greater than 200 m downgradient with respect to groundwater flow. The tunnel is approximately 50 m below ground level in this area; however, PWS3-7 is reported to be a borehole source. No further details of the source are available at the time of assessment and the exact source location and depth has not been verified and could be further upgradient, closer to the tunnel. Consequently, a potential effect on the capacity of the source cannot be ruled out. The potential magnitude of impact is considered to be minor, resulting in a potential slight significance of effect.

267) PWS3-13 is located at greater than 200 m from and downgradient from the tunnel in the area of the Newton-in-Bowland Compound portal. The tunnel is very shallow in this area and PWS3-13 is reported to be a spring source. Considering its distance from the tunnel, the potential magnitude of impact to the supply capacity is considered to be negligible, resulting in a potential neutral significance of effect.

268) At the Lower Houses Compound, PWS3-16 is located greater than 200 m from and downgradient from the tunnel. The tunnel is approximately 10 m deep in this area and the supply type (borehole or spring) for PWS3-16 is unknown. Considering its distance from the tunnel, the potential magnitude of impact to the supply capacity is considered to be negligible, resulting in a potential neutral significance of effect.

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

<u>Permanent Access Track</u>

270) A permanent access track is proposed to the north-east of the Lower Houses shaft. With limited activity and vehicle movement during operation, ground disturbance and 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 significance of effect.

Summary of Effects

271) A summary of the operational phase effects is shown in Table 7.32.

Table 7.32: Summary of Operational Phase Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
River Hodder (W477)	Medium	Change to flow regime	Permanent	Negligible	Neutral
Surface Water Quality					
River Hindburn (W478)	Very high	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Cod Gill (W206)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
River Hodder (W477)	Very high	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
		Localised erosion changing water quality	Temporary	Negligible	Neutral
Unnamed watercourse 384(W461)	Medium	Sediment laden runoff	Temporary	Negligible	Neutral
		Chemical pollution	Temporary	Negligible	Neutral
Groundwater					
PWS3-7	Medium	Reduction in source capacity	Permanent	Minor	Slight
Superficial aquifer – glacial till (diamicton)	Medium	Contamination associated with vehicle movements and accidental spillages at Lower Houses Compound and Newton-in-Bowland Compound.	Temporary	Negligible	Neutral
Secondary A bedrock aquifers	High	Contamination associated with vehicle movements and accidental spillages at Lower Houses Compound and Newton-in-Bowland Compound.	Temporary	Negligible	Neutral
PWS3-13 and PWS3-16	Medium	Reduction in source capacity	Permanent	Negligible	Neutral

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Impact	Significance of Effect (Pre-Mitigation)
Gamble Hole Farm Pasture	High	Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits.	Permanent	Moderate	Moderate – Significant

7.6.5 Decommissioning Phase

272) Following completion and commissioning of the new aqueduct, the existing Bowland section 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 Bowland Section has been commissioned. Therefore, it is likely that groundwater would enter the decommissioned aqueduct over time.

273) 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 the River Hodder through the existing outfall location. This outfall would remain in place after the commissioning of the Proposed Bowland Section.

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

Fluvial Geomorphology

275) During the decommissioning phase of the Proposed Bowland Section the only activity which would interact with watercourses identified within the fluvial geomorphology baseline would be discharge of groundwater ingress from the existing overflow structure.

276) Without any specific mitigation , this activity would have the potential to change the flow and sediment regimes, and cause bed and bank erosion.

Changes to Flow and Sediment Transportation Regimes

277) Groundwater ingress from the existing Haweswater Aqueduct would be discharged from the existing outfall location on the River Hodder once it has been decommissioned. The estimated groundwater ingress rate (based on upper limit 95%ile) is 139.5 l/s, which United Utilities have estimated based on observations made during inspections carried out in 2016. A Monte Carlo analysis[28] 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.

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

279) Table 7.33 shows that the decommissioned flow would not have a significant impact on the specific stream power of the River Hodder. Analysis of sediment entrainment capabilities show that there would be no change in the grain size of sediment transported after the decommissioning, during the flows assessed in Table 7.33.

280) Consequently, there would likely be little change to the baseline geomorphological processes and features as a result of the decommissioning flows from the decommissioned Haweswater Aqueduct. This has been assessed to have a negligible magnitude of impact on the River Hodder with a neutral significance of effect.

Table 7.33: River Hodder Specific Stream Power

Flow Percentile	Specific Stream Power - ω (W/m^2)	
	Baseline	Decommissioning Phase
Q95	1.5	1.8
Q50	5.2	5.6
Qmed (bankfull)	215	215.4

Bed and Bank erosion

[28] The use of randomness to solve a problem

281) The assessment of the changes to flow and sediment transportation considers a volumetric increase in flow across a given cross-section and is useful to consider downstream impacts. It does not, however, consider the manner with which groundwater ingress would be discharged, i.e. from a single point several metres above the toe of the bank. This discharge could lead to localised bed and bank erosion. This would disrupt the structure of the riffle that has formed at this location, most likely permanently removing coarse sediment which has built up within the channel.

282) The reach of the River Hodder where the outfall is present was observed as having potential for lateral adjustment, with the banks upstream showing evidence of scour. Weakening of the bed / bank structure through the discharge of groundwater ingress could increase the potential for scour to occur. This could lead to localised bank failure, which could lead to the undermining of the outfall and pipe bridge abutments.

283) Given the importance and general scarcity of coarse sediment features, such as riffles, to the geomorphological setting of the River Hodder and the potential for causing bank erosion, discharge of groundwater ingress has been assessed to have a moderate magnitude of impact. Therefore, the significance of effect would be moderate.

Surface Water Quality

284) During the decommissioning phase of the Proposed Bowland 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.

285) Without any specific mitigation , this activity would have the potential to cause exceedances of water quality standards, which are explained below.

<u>Exceedances of Water Quality Standards</u>

286) The discharge of groundwater ingress from the existing aqueduct has the potential to be polluted with a range of potential contaminates related to natural bedrock geology and current and historical land uses. Should groundwater be contaminated and discharged to the River Hodder there is the potential to impact surface water quality downstream from the existing outfall.

287) Due to the uncertainty of groundwater quality in the area around the Proposed Bowland Section it is anticipated that the magnitude of impact on surface water quality from decommissioning discharges to the River Hodder would be minor resulting in a significance of effect of moderate.

Groundwater

<u>Long-term Increase in Dewatering Impact</u>

288) Following the commissioning of the new aqueduct, the existing aqueduct would be retained. Ingress into the existing Haweswater Aqueduct is likely to occur over time. United Utilities have undertaken a modelling exercise to predict potential dewatering volumes by 2055 as the aqueduct deteriorates. This estimation does not take into account the geological settings and therefore, in low permeability areas, the natural geological properties could act as a more stringent limitation factor.

289) The United Utilities modelling predicted potential ingress rates of between 75.08 to 139.54 l/s for the entire existing Bowland section, over a length of about 16.5 km, equating to an ingress rate of 4.56E-03 to 8457E-03 l/s/m.

290) As discussed in the baseline section of this report, the existing aqueduct is located within bedrock, consisting predominantly of mudstone / shale and sandstone (grits), along with some limestone. The desk study conducted by Preene Groundwater Consulting Ltd[29] examined available information on groundwater levels in the vicinity of the existing aqueduct, estimating these to range from 190 to 340 mAOD. These levels place the groundwater potentiometric surface at some depth below ground

[29] Preene Groundwater Consulting Limited (2014) *op. cit.*

level along much of the route. Preene Groundwater Consulting Ltd[30] concluded that along deeper sections of the existing aqueduct, groundwater connection with the surface may be limited, except around major faults or the presence of more permeable strata. This is also confirmed by the draft GI data available at the time of writing. As a result, any dewatering effects occurring at depth would not be expected to impact on surface receptors such as watercourses and GWDTEs.

291) 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.[31] Permeability testing results from equivalent geology conducted during the GI carried out for the proposed Bowland Section were used in the SEEP modelling. Boundary conditions were set based on radii of influence calculated from the United Utilities modelled inflow rates, with a minimum radius of 50 m applied to account for known limitations in the methodology where the estimated radius of influence is quite small. Groundwater head above the tunnel was based on values derived from the initial GI results and the Hydrogeological Desk Study (Preene Groundwater Consulting Ltd).[32]

292) The SEEP modelling predicted potential groundwater drawdowns ranging from 1.8 m in the northern section of the existing aqueduct to less than 1 m in the central section and 1.2 m in the southern section. 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.

293) These are relatively small effects and, considering the depth of the tunnel through most of the Proposed Bowland Section, the potential magnitude of impact on the Secondary A bedrock aquifers would be negligible, giving a potential significance of effect of neutral.

294) However, there are a number of PWS in close proximity to the tunnel (PWS3-1, PWS3-2, PWS3-3 and PWS3-4, which are all borehole sources of unknown depth), and one which is close to the southern end of the section (PWS3-8, which is a spring) where the tunnel is shallower.

295) PWS3-8 is located within the Newton-in-Bowland Compound and is likely to be disrupted by the proposed Bowland Section. This is considered in preceding sections of this report and so it is not considered further here. Although the predicted effects of the decommissioned aquifer on the surrounding groundwater system are relatively small, there would be a potential minor magnitude impact on the capacity of PWS3-1, PWS3-2, PWS3-3 and PWS3-4, assuming a worst-case scenario. This would result in potential slight significance of effect. It should also be noted that the locations and abstraction details for PWS3-1, PWS3-2, PWS3-3 and PWS3-4 are unconfirmed at the time of this assessment.

Summary of Effects

296) A summary of the decommissioning phase effects is shown in Table 7.34.

[30] *Ibid*.
[31] GEOSLOPE International Ltd, Geostudio (2020) Version 10.2.1.19666.
[32] Preene Groundwater Consulting Limited (2014) *op. cit.*

Table 7.34: Summary of Decommissioning Phase Effects

Environmental / Community Asset	Sensitivity	Effect	Duration	Magnitude of Effect	Significance of Effect (Pre-Mitigation)
Fluvial Geomorphology					
River Hodder (W477)	Medium	Changes to flow and sediment transportation regimes	Long term	Negligible	Neutral
		Bed and bank erosion	Long term	Moderate	Moderate – Significant
Surface Water Quality					
River Hodder (W477)	Very high	Exceedance of discharge standards	Long term	Minor	Moderate – Significant
Groundwater					
PWS3-1, PWS3-2, PWS3-3 and PWS3-4	Medium	Reduction in capacity as a result of groundwater drainage into the decommissioned aqueduct. Locations and details are unconfirmed	Long term	Minor	Slight
Superficial aquifer – glacial till (diamicton)	Medium	Long term dewatering associated with decommissioning	Long term	Negligible	Neutral
Secondary A bedrock aquifers	High	Long term dewatering associated with decommissioning	Long term	Negligible	Neutral

7.7 Essential Mitigation and Residual Effects

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

298) 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

299) To mitigate the impact on the River Hodder from the two temporary outfalls, it is recommended that the location of the outfalls is adjusted (**Mitigation Item WE1**). The outfalls should be located so that they are not opposite each other, to minimise local scour.

300) In addition, to mitigate the impact on the River Hodder from the temporary access route and outfalls, the following would be recommended as part of the removal of the structures:

- Reinstate the natural bed and augment this with coarser material where necessary to promote bed stability and reduce the risk of channel incision and instability (**Mitigation Item WE2**)
- Place coarse material along the bank toe to stabilise the bank (**Mitigation Item WE3**)
- 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 WE4**)
- Reinstatement work be supervised by a geomorphologist or Ecological Clerk of Works with experience of channel restoration (**Mitigation Item WE5**).

301) These recommendations are aligned with restoration options for the River Hodder, proposed as part of the River Hodder Restoration Options Assessment[33]. For the reach between the B6478 and the inflow of Foulscale Brook, which includes the proposed access route crossing, the following restoration options are proposed and should not be impacted upon:

- Planting of riparian vegetation
- Fencing to reduce the risk of poaching
- In-channel improvements including berms and flow deflectors to increase sediment transport and improve hydraulic processes in a homogenous and overwide reach
- Investigation weir removal or fish passage
- Sediment augmentation downstream of the B6478 bridge.

302) To mitigate the impact on the River Hodder from increased fine sediment input, and to be in line with the CCoP, the surplus material storage at Newton-in-Bowland Compound (adjacent to Unnamed Watercourse 384) should be relocated. It is recommended that the material is at least 10 m from a watercourse and / or surface water drainage infrastructure. The current designs, although indicative, show the surplus material storage areas within 10 m of watercourses therefore, a residual impact of moderate with a significance of effect of moderate would remain for the River Hodder.

303) To mitigate the impact on Unnamed Watercourse 385 from the temporary access route the same mitigation measures would be recommended as part of the removal of the culvert as for the River Hodder.

304) To mitigate for the impacts anticipated as a result of discharge of groundwater ingress to the River Hodder it is recommended that geomorphological monitoring of the reach is undertaken to identify any

[33] Jacobs (2018) *NEP AMP6 Stocks Reservoir – River Hodder Restoration Options Assessment*.

movement in the riffle downstream and bank erosion (**Mitigation Item WE6**). This should be undertaken on a monthly basis for the first 12 months following commencement of discharge, then on a six-monthly basis (October and February). Review of the need for monitoring should be carried out after five years in consultation with the Environment Agency.

305) If any changes in the structure of the bed or evidence of bank erosion are identified, remedial action should be discussed with the Environment Agency. Action could take the form of repositioning the outfall to water level, gravel augmentation or installation of environmentally sensitive bank protection.

306) The River Hindburn would likely be impacted by the temporary access route crossing of Unnamed Watercourse 169. To mitigate for this, the following mitigation would be recommended for Unnamed Watercourse 169 as part of the removal of the culvert:

- Reinstate the natural bed and augment this with coarser material where necessary to promote bed stability and reduce the risk of channel incision and instability (**Mitigation Item WE7**)
- Place coarse material along the bank toe to stabilise the bank (**Mitigation Item WE8**)
- Reinstatement work be supervised by a geomorphologist or Ecological Clerk of Works with experience of channel restoration (**Mitigation Item WE9**).

307) Mitigation would be required on Cod Gill for the impact of the discharge of the commissioning flows. Green bank protection would be recommended opposite the outfall and at locations where erosion is already taking place, with scour matting also placed around the outfall to minimise localised bed scour (**Mitigation Item WE10**).

308) For both watercourses likely to be impacted by the commissioning flow (Cod Gill and the River Hindburn), monitoring would be required (**Mitigation Item WE12**). This would likely take the form of monitoring changes to 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 outfall, 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.
Surface Water Quality

309) To mitigate the impact on the River Hodder from sediment laden runoff during the enabling and construction phases, supervision by an Environmental Clerk of Works would be carried out (**Mitigation Item WE17**[34]). This supervision would enable any ground-stripping activities and storage of material to be contained where practicable and measures detailed within the CCoP (Appendix 3.2) employed to mitigate against any uncontrolled releases of sediment laden runoff to the River Hodder (**Mitigation Item WE18**). All works would be required to comply and be carried out within an appropriate method statement when working within the functional floodplain.

310) To mitigate the impact of the identified surface water habitat (Lowland Fen), the following measures would be recommended, in conjunction with those mitigation items identified for the Gamble Hole Farm Pasture GWDTE:

- Prior to commencement of works, Environmental Clerk of Works and appointed contractor walk the planned route to identify any surface water flow pathways and localised depressions which would convey water across the habitat (**Mitigation Item WE19**)
- Minimise excavation of habitat as much as practicably possible, and avoid repeated tracking over the habitat, i.e. keeping the disturbance corridor as minimal as possible (**Mitigation Item WE20**)
- Consideration of introducing a series of pipes, wrapped in a geotextile at the base of the subbase to maintain hydrological connectivity through the access track (**Mitigation Item WE21**)
- Avoidance of discharging construction runoff into habitat (**Mitigation Item WE22**)

[34] Following review of the mitigation measures, Mitigation Items WE13-WE16 have been intentionally removed

- Appropriate mitigation to be employed across the area of habitat being crossed (and associated with the culvert crossing). Mitigation such as the installation of splashguards along the edge of the access track to avoid material / silt laden water running off the track and smothering the habitat (**Mitigation Item WE23**).

311) As outlined in the fluvial geomorphology section above, monitoring of the commissioning flows on the watercourses which may be potentially impacted is recommended to avoid degradation in water quality arising from bank disturbance (**Mitigation Item WE24**). 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.

312) During the decommissioning phase, discharge of groundwater ingress from the existing aqueduct, discharged via the existing outfall. There would be potential for this water to be polluted with a range of potential contaminates 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 River Hodder from decommissioning flows on surface water quality, it is recommended that further assessment is undertaken.

313) 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 the River Hodder are not having a significant adverse impact upon surface water quality
- Understand the long-term chemistry of the groundwater surrounding the aqueduct.

314) 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 7.35 outlines the proposed water chemistry parameters to be tested as well as the methodology and sampling frequency of each parameter.

Table 7.35: 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
Ammonium	
Phosphate	

Analytical Parameters (Water Analysis)	Proposed Type and Frequency of Analysis
Sulphate	inorganics parameter concentrations.
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.

315) 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 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 Proposed Bowland Section 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.

316) 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 7.35, the timing of monthly sampling could be adjusted to capture a range of flow conditions to better understand the link between flow and concentrations of selected parameters.

317) 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 should be consulted and agreement sought before any environmental standards are adjusted.

318) Until a water quality monitoring programme begins sampling decommissioning flows, and an initial dataset can be established, it is premature to propose appropriate mitigation measures. Any mitigation measures implemented should be appropriate to the pollutant of concern. In general, 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.

319) 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 are to be agreed in a suspensive condition to the consent of the Proposed Bowland Section

7.7.2 Groundwater

320) The following potential impacts have been assessed as of moderate or greater significance and mitigation measures should be considered.

Private Water Supplies

321) The following PWS have been identified as at potential risk of impact to flow, water quality or associated infrastructure during enabling and construction phases: PWS3-8, PWS3-14, PWS3-15 and PWS3-16. Site visits and landowner site meetings would be required to confirm the nature and location of the sources in order to ascertain whether direct or indirect impacts are likely and to plan monitoring measures where required (**Mitigation Item WE25**). This would include confirmation of pipe networks to check whether there would be any additional impact on the infrastructure.

322) Should the location of sources associated with PWS3-8, PWS3-14 and PWS3-15 be confirmed, a replacement strategy may need to be put in place if the sources cannot be safe guarded during the proposed works. Should safe guard measures be implementable for PWS3-8, PWS3-14 and PWS3-15, monitoring of flow and quality would be required, alongside monitoring of PWS3-16 (**Mitigation Item WE26**). However, this would be confirmed following site visits. Should monitoring indicate an impact during the proposed work, a temporary replacement water supply would be provided. Should monitoring demonstrate a long-term impact, the supply source would be replaced. Should pipe networks or other associated infrastructure with a given private water supply be disrupted by the proposed work, these would be repaired or replaced (**Mitigation Item WE27**).

323) Despite no impact expected on PWS3-1, PWS3-2, PWS3-3, PWS3-4, PWS3-7, PWS3-12 and PWS3-13 (based on the information available at this stage), full details of the sources are currently unknown. A site visit and landowner site meetings would be required to confirm the nature and location of the sources to confirm the initial assessment. No monitoring requirement would be anticipated for these PWS; however, this would be confirmed following site visits.

324) With the implementation of the mitigation measures outlined above, all residual potential impacts would be of neutral significance of effect.

Watercourses

325) To mitigate the impact of dewatering during construction on Unnamed Watercourse 385, it is proposed that (treated) construction water is discharged at the head of the watercourse (**Mitigation Item WE28**). This would be limited to greenfield runoff rates for the catchment upgradient of the portal in order to mimic catchment hydrology as much as possible.

GWDTEs

326) Table 7.36 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 7.36: 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 WE29**)	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 WE30**)	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 WE31**)	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 WE32**)	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 WE33**)	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 WE34**)	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.

327) In addition, the following specific mitigation measures are recommended to be put in place:

- Topsoil stripping and any activity that would have a direct / significant impact on habitats at Lower Houses Cottage, Gamble Hole Farm Pasture, The Coach House and River Hodder North should be minimised within the Lower Houses Compound and Newton-in-Bowland Compound (**Mitigation Item WE35**)
- During the detailed design phase, opportunities for hydroecological compensation should be explored to offset short and long-term impacts expected to habitats at Gamble Hole Farm Pasture, including, e.g. outline habitat creation, enhancement and management proposals (**Mitigation Item WE36**)
- A feasibility assessment should be undertaken during the detailed design phase, for bridging the access road (associated with the Newton-in-Bowland Compound) over Gamble Hole Farm Pasture. This would avoid the need for excavation and reduce potential direct impacts to highly sensitive habitats at the site (**Mitigation Item WE37**)
- Opportunities to reduce compaction effects by spreading the load of heavy vehicles and plant along access areas should be considered during the detailed design phase. This would reduce potential impacts to habitats at Gamble Hole Farm Pasture and River Hodder North (**Mitigation Item WE38**)
- Clay bunds to be used to prevent backfilled open-cut trenches from acting as a groundwater drain within the Newton-in-Bowland Compound. This would mitigate against long-term potential impacts to Gamble Hole Farm Pasture (**Mitigation Item WE39**).

328) Table 7.37 outlines the residual effects associated with the proposed development, 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 7.37: Summary of Residual Effects to GWDTEs

Site Name	Sensitivity	Phase / Effect Type / Mitigation	Highest Residual Magnitude of Impact	Highest Residual Significance of Effect
Lower House Cottage	Medium to low	Enabling phase: intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (Mitigation would reduce the impact from moderate to negligible across the site, but residual effects with a potential neutral significance remain due to the works being located upgradient of the site.)	Negligible	Neutral
Gamble Hole Farm Pasture	High	Enabling phase: intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (Mitigation would aim to offset / reduce potential impacts as much as feasibly possible.)	Major to minor	Large to slight – Significant
		Construction phase: alterations to flows and levels due to Newton-in-Bowland portal dewatering. (Mitigation would aim to offset / reduce potential impacts as much as feasibly possible.)	Major to minor	Very large to slight – Significant
		Construction phase: alterations to flows and levels due to Newton-in-Bowland open-cut connection and overflow dewatering. (Mitigation would aim to offset / reduce potential impacts as much as feasibly possible.)	Major to minor	Large to slight – Significant
		Enabling phase: changes to groundwater quality due to ground disturbance associated with the Newton-in-Bowland Compound, and leaks and spills of fuels and chemicals. (Mitigation would aim to offset / reduce potential impacts as much as feasibly possible.)	Moderate to minor	Moderate to slight – Significant
		Operation phase: intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits. (Mitigation would aim to offset / reduce potential impacts as much as feasibly possible.)	Moderate to minor	Moderate to slight – Significant
The Coach House	Medium	Enabling phase: intercept flows in short term, including ground compaction, topsoil stripping, construction of access tracks (Mitigation would reduce the impact from moderate to negligible to the southern sub-site, but residual effects with a potential neutral significance remain due to the works being located across-gradient of the site and the sensitivity of the receptor.)	Negligible	Neutral

Site Name	Sensitivity	Phase / Effect Type / Mitigation	Highest Residual Magnitude of Impact	Highest Residual Significance of Effect
River Hodder North	Medium	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 across the site.)	Major	Large – Significant
		Enabling phase: changes to groundwater quality due to ground disturbance associated with the Newton-in-Bowland 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, due to the sensitivity of the receptor and direct nature of the works footprint.)	Moderate	Moderate – Significant

7.7.3 Summary

329) A summary of mitigation and residual effects is shown in Table 7.38.

Table 7.38: Summary of Mitigation and Residual Effects

Receptor	Mitigation[35]	Magnitude (with Mitigation)	Residual Effect and Significance
Fluvial Geomorphology			
River Hodder (W477)	▪ Adjust outfall location (**WE1**) ▪ Reinstate the natural bed and augment the sediment (**WE2** and **WE3**) ▪ Stabilise the bank (**WE4** and **WE**5).	Minor	Slight
	▪ Geomorphological monitoring (**WE6**).	Moderate	Moderate – Significant
	▪ No mitigation possible for impacts of soil storage.	Moderate	Moderate – Significant
Unnamed Watercourse 385 (W462)	▪ Reinstate the natural bed and augment the sediment (**WE2** and **WE3**) ▪ Stabilise the bank (**WE4** and **WE**5).	Minor	Slight
River Hindburn (W478)	▪ Reinstate the natural bed and augment the sediment on Unnamed Watercourse 169 (**WE7**) ▪ Stabilise the bank on Unnamed Watercourse 169 (**WE8**) ▪ Erosion monitoring (**WE12**) ▪ Remediation for commissioning flows as required (**WE9**).	Negligible	Neutral
Cod Gill (W206)	▪ Flow monitoring (**WE12**) ▪ Erosion monitoring (**WE12**).	Minor	Slight
Surface Water Quality			
River Hodder (W477)	▪ Supervision by geomorphologist (or Environmental Clerk of Works) (**WE17**) ▪ Adherence to excavation and storage protocols when working in the floodplain (**WE18**).	Negligible	Neutral
	▪ Water quality monitoring plan for decommissioning flows.	Minor	Moderate – Significant

[35] Mitigation items WE13-16 inclusive have been intentionally omitted.

Receptor	Mitigation[35]	Magnitude (with Mitigation)	Residual Effect and Significance
Surface water habitat (Lowland Fen)	▪ Environmental Clerk of Works and contractor walkover to identify flow pathways within habitat (**WE24**) ▪ Excavation / soil stripping / ground disturbance to be minimised (**WE20**) ▪ Maintain hydrological connectivity through the track (**WE21**) ▪ Avoid construction runoff discharges into habitat (**WE22**) ▪ Track edge mitigation, e.g. splash guards (**WE23**).	Minor	Slight
Groundwater			
PWS3-8, PWS3-14, PWS3-15, PWS3-16	▪ Site visit and landowner meeting to confirm location and nature of source and associated infrastructure (**WE25**) ▪ Monitoring of flow and quality during the proposed work (**WE26**) ▪ Replacement water supply (temporary or permanent) if indicated by monitoring. Repair or replacement of associated infrastructure if required (**WE27**).	Negligible	Neutral
PWS3-1, PWS3-2, PWS3-3, PWS3-4, PWS3-7, PWS3-12, PWS3-13	▪ Site visit and landowner meeting to confirm location and nature of source and associated infrastructure (**WE25**) ▪ None required at present, pending confirmation from site visit.	Negligible	Neutral
Surface water feature – Unnamed Watercourse 385	▪ Discharge of (treated) construction discharge to watercourse (**WE28**).	Negligible	Neutral
Lower House Cottage	▪ Standard best practice mitigation measures set out in Table 7.36 to increase the likelihood of recovery of the GWDTE (**WE29 – WE34**) ▪ Avoidance of topsoil stripping in the Lower Houses Compound immediately upgradient of the site, and any activity that would have a significant impact on habitats within Lower House Cottage (**WE35**).	Negligible	Neutral

Receptor	Mitigation[35]	Magnitude (with Mitigation)	Residual Effect and Significance
Gamble Hole Farm Pasture	▪ Standard best practice mitigation measures set out in Table 7.36 to increase the likelihood of recovery of the GWDTE (**WE29 – WE34**) ▪ Exploring opportunities for hydroecological compensation to offset short and long-term impacts to habitats at Gamble Hole Farm Pasture (**WE36**) ▪ Minimising topsoil stripping in the Newton-in-Bowland Compound, and any activity that would have a direct impact on habitats within Gamble Hole Farm Pasture (**WE35**) ▪ Undertake a feasibility assessment for bridging the access road (associated with the Newton-in-Bowland Compound) over the Gamble Hole Farm Pasture site (**WE37**) ▪ Spreading the load of heavy vehicles and plant to reduce compaction effects associated with the Newton-in-Bowland Compound access area (**WE38**) ▪ Clay bunds to be used to prevent backfilled open-cut trenches from acting as a groundwater drain within the Newton-in-Bowland Compound (**WE39**).	Major to minor	Very large to slight – Significant
The Coach House	▪ Standard best practice mitigation measures set out in Table 7.36 to increase the likelihood of recovery of the GWDTE (**WE29 – WE34**) ▪ Avoidance of topsoil stripping in the Newton-in-Bowland Compound immediately upgradient of the site, and any activity that would have a significant impact on habitats within The Coach House (**WE35**).	Negligible	Neutral
River Hodder North	▪ Standard best practice mitigation measures set out in Table 7.36 to increase the likelihood of recovery of the GWDTE (**WE29 – WE34**) ▪ Minimising topsoil stripping in the Newton-in-Bowland Compound access area, and any activity that would have a direct impact on habitats within River Hodder North (**WE35**)	Major	Large – Significant

Receptor	Mitigation[35]	Magnitude (with Mitigation)	Residual Effect and Significance
	▪ Spreading the load of heavy vehicles and plant to reduce compaction effects associated with the Newton-in-Bowland Compound access area (**WE38**).		

7.8 Cumulative Effects

330) The following section provides an overview of the potential cumulative effects from different proposed developments and land allocations, in combination with the Proposed Bowland 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 Bowland Section.

331) 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.

332) 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), Volume 5 (proposed off-site highways works and satellite compounds), and Volume 6 (Proposed Ribble Crossing).

333) Based on professional judgement, it was concluded that there are no proposed third party developments or land allocations in local development plan documents identified within 5 km of the Proposed Bowland Section that would be likely to cause a cumulative effect on any watercourses identified in the fluvial geomorphology or water quality baseline, or on the groundwater environment. No cumulative assessment was therefore undertaken in connection Water Environment.

7.8.1 Proposed Ribble Crossing

334) The impact on water environment for the Proposed Ribble crossing has been assessed. This is reported in Volume 6.

335) 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. For Coplow Brook and Greg Sike the impacts would likely be moderate with a moderate significance of effect. These impacts would be mitigated by reinstating natural bed features and using a biodegradable geotextile on the banks to allow for vegetation re-establishment. It is recommended that reinstatement would be supervised by an Environmental Clerk of Works. This would result in a residual impact of negligible with a neutral significance of effect.

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

337) For groundwater there could be the creation of vertical pathway for surface contamination to migrate as a result of piling within bedrock and alluvial aquifers. This would likely have a moderate impact with a moderate significance of effect. 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.

7.8.2 Off-Site Highways Works

338) Volume 6 assesses the environmental effects of the proposed off-site highways works. No likely significant effects on the water environment are identified in Volume 6.

7.9 Conclusion

339) 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 Bowland Section. This has included an assessment of the impacts on fluvial geomorphology, surface water quality and groundwater.

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

341) For fluvial geomorphology, it is recommended that the impact of discharge of surface water runoff on the River Hodder is mitigated by adjusting the location of the proposed outfalls. Further mitigation would be required on the River Hodder for the impact of the construction of the temporary outfalls and access routes and on Unnamed Watercourse 385 from the temporary access route. This could be done by reinstating the natural bed and stabilising the banks during the removal of the structures. This would also be required on Unnamed Watercourse 169 to mitigate the impact that the access route crossing on Unnamed Watercourse 169 would have on the River Hindburn downstream.

342) The assessment has shown that there would be an impact from the discharge of commissioning flows on Cod Gill and the River Hindburn. It is recommended that the geomorphological features of the watercourses downstream of the discharge point are monitored. Reinstatement work on Cod Gill, following the removal of the temporary outfall, would also be required.

343) Monitoring is also recommended on the River Hodder to mitigate the impact of groundwater ingress being discharged during decommissioning. If any changes in the geomorphological environment are identified, remedial action would be required.

344) To ensure applicable surface water quality standards within the River Hodder would be maintained during the enabling and construction phases, it is recommended that works are supervised by a geomorphologist or Environmental Clerk of Works and excavation and storage protocols are adhered to when working in the floodplain. In addition, it is recommended that a water quality monitoring plan is carried out to mitigate the impact on River Hodder from the decommissioning flows.

345) To mitigate the surface water impacts on the Lowland Fen (a surface water habitat) it is recommended that flow pathways are identified on site with the contractor and an Environmental Clerk of Works, ground disturbances are minimised, hydrological connectivity through the access track is maintained, avoid construction runoff discharges into the habitat and employ track edge mitigation, e.g. splash guards.

346) For PPWS3-8, PWS3-14, PWS3-15, PWS3-1, PWS3-2, PWS3-3, PWS3-4, PWS3-7, PWS3-12 PWS3-13,, PWS3-15 and PWS3-16 site visits and landowner meetings are recommended to confirm the location and the nature of the source of the PWS and any associated infrastructure. The site visits at PWS3-8, PWS3-14, PWS3-15 and PWS3-16 would also determine the requirements for monitoring of groundwater flow and quality and the requirements for replacing the water supply during the works. Should the location of the sources for PWS3-8, PWS3-14 and PWS3-15 be confirmed as being within the footprint of the Newton-in-Bowland Compound, a replacement strategy may be needed for these supplies.

347) To mitigate the impact of dewatering during construction on Unnamed Watercourse 385, it is recommended that construction water is discharged at the head of the watercourse and discharge is limited to greenfield runoff rates.

348) A number of standard and site-specific mitigation measures have been proposed to reduce impacts on GWDTEs. However, in some instances, direct impacts could not be avoided.

349) For surface water quality and groundwater-related receptors except GWDTEs, the mitigation measures reduce the significance of effect to slight or lower. There may be, however, large to negligible residual impacts on some GWDTEs.

350) The residual significance of effect remains as moderate for the decommissioning flows to potentially impact 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 reduced.

351) For fluvial geomorphology, the mitigation measures reduce the significance of effect to slight or lower for most impacts. For the impact of groundwater ingress being discharged during decommissioning on the fluvial geomorphology of the River Hodder the residual effect is moderate.

352) Proposed developments within 5 km of the Proposed Bowland Section have been identified. Cumulative effects have been assessed in terms of the additional and combined effects. None of the developments identified are likely to cause a cumulative effect on fluvial geomorphology, surface water quality or groundwater.

7.10 Glossary and Key Terms

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