Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

Environmental Statement

Volume 4

Appendix 8.1: Flood Risk Assessment

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Water for the North West

Jacobs

Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

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Jacobs U.K. Limited

5 First Street
Manchester
M15 4GU
+44(0)161.235.6000
+44(0)161.235.6001
www.jacobs.com

Contents

1. Introduction

1.1 Purpose

1) This Flood Risk Assessment (FRA) has been prepared to support the planning application for the Proposed Bowland Section of the Haweswater Aqueduct Resilience Programme (HARP). The assessment of flood risk has been carried out in combination with the Proposed Bowland Section design development through the Environmental Impact Assessment (EIA) process and informs Chapter 8: Flood Risk of the Environmental Statement (ES).

1.1.1 Scope and Structure

2) This FRA has been carried out in accordance with the National Planning Policy Framework (NPPF)[1] and the Planning Practice Guidance (PPG).[2] Complying with planning policy would promote a scheme that would be appropriate given the level of local flood risks, would be safe during the construction and operational phases of its lifetime, and would not increase flood risk both on site and elsewhere.

3) This FRA will provide the evidence to demonstrate that the Proposed Bowland Section complies with the above requirements. The structure of the FRA is outlined below:

- Section 2 describes the methodology adopted to define the scope of this assessment and details the methodology of the main assessment along with key datasets, assumptions and limitations.
- The assessment of flood risk has been used to:
  - Define the level of flood risk to the Proposed Bowland Section
  - Determine the potential impacts of the Proposed Bowland Section on flood risk elsewhere
  - Outline any proposed measures required to mitigate the risk and impacts identified.
- The assessment is reported across four sections, linked to key phases of the design life of the Proposed Bowland Section, as detailed below:
  - Enabling and construction phase (Section 3)
  - Commissioning phase (Section 4)
  - Operational phase (Section 5)
  - Decommissioning of the existing aqueduct (Section 6)
- Section 7 summarises the key flood risk issues and any additional mitigation measures identified.
- Annexe A provides further detail of the results of the flood risk assessment against each source of flooding identified.

1.2 Proposed Programme of Works Overview

4) The existing 110 km Haweswater Aqueduct takes raw water from Haweswater Reservoir in the Lake District National Park along a 16 km section of the aqueduct to a water treatment works near Kendal. From this water treatment works the aqueduct conveys treated water to customers in Greater Manchester, Cumbria and Lancashire.

5) The aqueduct comprises six existing tunnel sections replaced with five proposed tunnels (generally 2.6 m internal diameter). The flow of water along the entire length of the aqueduct is achieved by gravity, with no energy-consuming pumps involved in supplying the water from north to south. Out of

[1] Ministry for Housing, Communities and Local Government (2018) *National Planning Policy Framework*. [Online] Available from: https://www.gov.uk/government/publications/national-planning-policy-framework--2. [Accessed: 22-05-20].
[2] Ministry for Housing, Communities and Local Government (2019) *Planning Practice Guidance*. [Online] Available from: https://www.gov.uk/government/collections/planning-practice-guidance. [Accessed: 22-05-20].

the total 110 km length of the aqueduct, the Proposed Programme of Works on the single line sections accounts for just under half this distance, about 53 km.

1.2.1 Proposed Bowland Section

6) At the central section of the aqueduct the proposed Bowland Section would be located within the administrative area of Lancashire County Council. The north of the section would fall within the Lancaster City area whilst the southern section would be located within Ribble Valley Borough. The Proposed Bowland Section would run for approximately 16 km between Wray and Newton-in-Bowland.

7) The existing aqueduct would be replaced with a single tunnel, identified as the Proposed Bowland Section. It would be constructed by tunnel boring below ground level with short open-cut surface trenching sections at each end to connect into the existing aqueduct.

8) The new tunnel would be bored from south to north, with a launch portal at Newton-in-Bowland Compound (south) and reception shaft at Lower Houses Compound (North). Further details on the tunnel boring and associated works are provided within Chapter 3: Design Evolution and Development Description of the ES. A plan showing the location and layout of the Proposed Bowland Section is presented on Figure 1.

9) The ES for the Proposed Bowland Section has defined five distinct project phases linked to the design life of the scheme:

- Enabling works
- Construction
- Commissioning
- Operation
- Decommissioning.

10) An overview of the key activities and infrastructure components of each of these phases is presented below. Drawings showing the layout of the enabling and construction works are presented within Annexe C. A further description of the Proposed Bowland Section is provided in Chapter 3: Design Evolution and Development Description of the ES.

11) Subject to planning permission, the proposed Programme of Works would start in 2023, with construction works. The works would ultimately reach completion and commissioning in 2029.

1.2.2 Enabling Works

12) Enabling works would include fencing off working areas and preparing sites ready for the construction and would include:

- Two compound sites, one at each end of the proposed tunnel, to provide areas for plant, machinery, equipment, welfare, offices and vehicle movements
  - The Lower Houses Compound would be located at the northern end of the Proposed Bowland Section and would comprise a Tunnel Boring Machine (TBM) Reception Site Compound with temporary access road from an unclassified road to the south
  - The Newton-in-Bowland Compound would be located at the southern end of the Proposed Bowland Section and would include a drive portal from which the tunnel would extend to the Lower Houses Compound in the north
- Surface water drainage systems serving compound sites
- Construction access tracks and associated drainage linking compounds to the public road network. This would include the construction of a temporary access road and temporary bridge across the River Hodder to enable construction traffic to bypass the village of Newton-in-Bowland.

1.2.3 Construction

13) Construction works would take place within construction compounds, within tunnels and on public highways and access routes and would include:

- Tunnel boring construction
  - The Proposed Bowland Section would be constructed using a double shield TBM
  - The new tunnel would be driven (launched) from the Newton-in-Bowland Drive Portal Compound (south end) to the Lower Houses Reception Shaft Compound (north end). The tunnel between the Newton-in-Bowland Compound and Lower Houses Compound shafts would have an internal diameter of approximately 3.5 m and would be approximately 16 km in length. The maximum depth of the tunnel would be approximately 295 m below ground level
  - Arisings from tunnel construction would be brought to the surface at the Newton-in-Bowland Compound and stored temporarily before being taken off to Waddington Fell Quarry located approximately 3 km to the south-east
  - Temporary surface water drainage and dewatering of groundwater from deep excavations and tunnels would be attenuated and treated before discharge into the receiving watercourse or drain
- Open-cut trenches would be excavated to enable the construction of multi-line siphons to join the existing aqueduct to the new tunnel at both the north and south ends of the Proposed Bowland Section
- The construction of permanent infrastructure, including above-ground installations such as new valve house buildings to control flow within the aqueduct and air valves along the multi-line siphon that would connect the new tunnel to the existing aqueduct
- Restoration of the enabling works to their pre-construction condition.

1.2.4 Commissioning

14) Following the construction phase, a commissioning process would be required during which the proposed sections of tunnel would be flushed through with potable water to sterilise the tunnel. This wash water would then be attenuated in two or three attenuation lagoons (approximately 50 m long, 25 m wide and 2 m deep) located within the Lower Houses and Newton-in-Bowland compound areas. Water would then be discharged to Cod Gill or the River Hodder via a de-chlorination plant at a maximum rate of 25 l/s. The commissioning process would take approximately four to six weeks.

1.2.5 Operations

15) For most of the length of the Proposed Bowland Section there would be no permanent above-ground structures with a large portion of the new sections of aqueduct being located deep below ground level.

16) Operational phase activities and features of relevance to the FRA would therefore be limited to operation of the proposed valve house buildings and air valves which would be accessed via existing permanent access tracks.

1.2.6 Decommissioning

17) Following completion and commissioning of the new replacement section, the old tunnel sections of the existing aqueduct would be taken out of service. A future maintenance and usage strategy for the redundant sections of aqueduct is being prepared; however, it was not available at the time of preparing this FRA and has therefore not been considered.

18) The existing overflow structure would however remain in operation and would link both the decommissioned aqueduct and the Proposed Bowland Section to the River Hodder via an overflow weir at the Hodder North Well. This overflow would protect the siphon sections of the new aqueduct from excessive pressure and would provide a discharge location for groundwater ingress from the decommissioned aqueduct.

2. Scope and Methodology

2.1 Introduction

19) The assessment of flood risk has been undertaken over two stages. This includes a scoping and a main phase in line with the development of the EIA and the Proposed Bowland Section design. This FRA only documents the findings of the main phase in support of the Proposed Bowland Section design as outlined in the planning application. However, a summary of the scoping process and its results are presented in the following sections along with key datasets, assumptions and limitations.

2.2 Assessing Flood Risk

2.2.1 Source-Pathway-Receptor

20) Flood risk is conceptualised using the source-pathway-receptor model. For a flood risk to be present each of the three elements is required:

- A source of flood water such as a river or groundwater body
- A pathway that enables the flow of flood water from a 'source' to a 'receptor'. This could include low-lying land within a floodplain or permeable strata that enable groundwater to seep to the surface, or construction activities such as tunnelling
- A receptor such as a person, property or habitat that may be impacted by a flood event.

21) Flood risk is therefore dependent on all elements being present and is assessed in terms of the probability (likelihood) of an event occurring and the consequence of the flood.

2.2.2 Probability

22) In this report the probability of flooding is defined using Annual Exceedance Probability (AEP). This is the preferred approach in comparison to the annual maximum return period (e.g. 1 in 100-year event). This is due to the potential misconception that return periods are associated with a regular occurrence rather than an average recurrence interval. For example, it is sometimes assumed that the 1 in 100-year event flood would occur once every 100-years. However, events with a magnitude of the 1 in 100-year event have a 1 % chance of being exceeded in any one year. Table 1 provides a comparison of AEP to return periods to aid the understanding of flood frequency.

Table 1: Equivalent annual exceedance probabilities and return periods

AEP	10 %	3.33 %	2 %	1.33 %	1 %	0.1 %
Return Period	1 in 10-year	1 in 30-year	1 in 50-year	1 in 75-year	1 in 100-year	1 in 1000-year

2.2.3 Consequence

23) The consequence of flooding is dependent on two factors:

- Exposure – For example, the number of people or properties potentially affected
- Vulnerability – The potential for people or property to be harmed or damaged.

24) Floods impact both individuals and communities, and have social, economic, and environmental consequences. These can be both negative and positive and can include direct and indirect loss.

25) With regards to development and flood risk, vulnerability is largely driven by the type of development proposed or affected. Different classes of vulnerability are defined in in Table 2 of PPG Flood Risk and Coastal Change.[3] In accordance with this table, the Proposed Bowland Section is classified as 'water

[3] Department for Communities and Local Governments (2019) Planning Practice Guidance. [Online] Available from: https://www.gov.uk/guidance/flood-risk-and-coastal-change#Table-2-Flood-Risk-Vulnerability-Classification. [Accessed: 22-05-20].

transmission infrastructure' and is listed as 'Water-Compatible Development'. The construction of water-compatible development is permitted within all Flood Zones defined by the Flood Map for Planning.

2.2.4 Impacts

26) The assessment of the flood risk impacts as a result of the Proposed Bowland Section and the magnitude of the change in flood risk considers the potential effects on all elements of flood risk including flood frequency, extent, depth, velocity and combinations of these components.

27) The duration of changes to flooding is also considered when assessing flood risk impacts, where a distinction is made between permanent changes and temporary changes where the effect would cease to be felt after a period. Temporary changes can be long term or short term in nature.

28) Embedded mitigation measures are also considered when determining potential impacts on flood risk. These measure form part of an optimised design used to reduce the significance of flood risk effects, for example:

- Following the sequential approach to avoid placing assets, features and activities within areas at high flood risk where possible
- Discharging surface water runoff as high up the drainage hierarchy and implementing Sustainable Drainage Systems (SuDS) where possible, to minimise the impact on the receiving watercourse
- Managing of groundwater discharges within the surface water drainage system.

29) It is assumed that good practice mitigation measures would be applied where the design has not been fully developed. Details of good practice are provided within the Construction Code of Practice (CCoP), Appendix 3.2 of the Environmental Statement.

2.2.5 Links to the Environmental Statement

30) The EIA process adopts a slightly different assessment model to flood risk (sensitivity x magnitude of change = significance), where;

- The sensitivity of a feature or resource is typically determined by, among other things, its level of designation or protection (e.g. importance, value or rarity), its susceptibility to or ability to accommodate change. Within the context of this FRA, sensitivity is a function of the likelihood of flooding and the potential consequences (i.e. baseline flood risk)
- The magnitude of change is a measure of the scale or extent of the change in the baseline condition, irrespective of the value of the feature or resource(s) affected (i.e. impact on flood risk)
- The significance of the overall flood risk is a product of the sensitivity of the resource or feature and the magnitude of the impacts.

31) Whilst the flood risk assessment model (probability x consequence = risk) will be used within this FRA, technical evidence provided in this FRA will be used to inform Chapter 8 (Flood Risk) of the Proposed Bowland Section ES. Annexe B therefore provides a set of assessment criteria used within the ES to define sensitivity, magnitude of change and significance.

2.3 Scoping Phase Assessment

32) During the scoping phase of the EIA, a high-level assessment of flood risk was undertaken to identify which sources of flood risk were present within the Proposed Bowland Section and to identify those flood sources or high-risk or high-impact elements of the Proposed Bowland Section that would require further detailed assessment during the main phase of the EIA.

2.3.1 Scoping Phase Sources of Information and Data

33) The scoping assessment was a high-level qualitative assessment based on the following readily available sources of development and flood risk information and datasets, including:

- Conceptual designs for the construction and operation of the Proposed Bowland Section provided by United Utilities
- Environment Agency Flood Map for Planning[4]
- Environment Agency Risk of Flooding from Surface Water Mapping[5]
- Environment Agency Reservoir Flood Mapping
- British Geological Survey (BGS) mapping[6]
- BGS groundwater flooding susceptibility maps[7]
- Ordnance Survey datasets including 1:25,000 scale mapping
- The Lancaster City Strategic Flood Risk assessment[8]
- The Ribble Valley Strategic Flood Risk assessment[9]
- United Utilities asset data
- A web search of historical flood incidents
- The Draft Ground Investigation (GI) Factual Report (for the groundwater flood risk assessment)[10]

2.3.2 Scoping Assessment Summary

34) Table 2provides a summary of the findings of the scoping flood risk assessment and identifies those sources of flood risk or Proposed Bowland Section design features 'scoped in' for consideration during the main phase flood risk assessment (this report).

Table 2: Scoping phase assessment, Bowland Section

Flood Source / Assessment Element	Assessment Summary	Conclusion
Assessment Area The assessment area of the Proposed Bowland Section defines the area used to identify sources of flood risk and the extents of possible scheme impacts.	The flood risk assessment would not have a fixed assessment area. The assessment would focus on the area within the planning application boundary and specifically on the surface and shallow works. As the design developed, the assessment would be extended to include areas downstream of the planning application boundary and areas of deep tunnelling if appropriate due to the magnitude of the impacts and the sensitivity of the potential receptors.	Assessment area varies according to source
Coastal Flood Risk Flooding originating from the sea where water levels exceed the normal tidal range and flood onto	The Proposed Bowland Section would be approximately 17 km from the River Lune Estuary and would be at a minimum elevation of approximately 130 m above Ordnance Datum (AOD).	Scoped out

[4] Environment Agency (2020a) *Flood Map for Planning*. [Online] Available from: https://flood-map-for-planning.service.gov.uk/. [Accessed: June 2020].
[5] Environment Agency (2020b) *Risk of Flooding from Surface Water Mapping*. [Online] Available from: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map. [Accessed: June 2020].
[6] British Geological Survey (BGS) (2020) Geology of Britain viewer (classic). [Online] Available from: https://mapapps.bgs.ac.uk/geologyofbritain/home.html. [Accessed: June 2020].
[7] BGS (2020) BGS Groundwater Flooding Susceptibility Dataset [Accessed in 2020]
[8] Lancaster City Council (2007) *Strategic Flood risk Assessment*. [Online] Available from: https://www.lancaster.gov.uk/assets/attach/1427/Strategic%20Flood%20Risk%20Assessment%20(Jacobs%202007).pdf. [Accessed: June 2020].
[9] Ribble Valley (2010) *Level 1 Strategic Flood Risk Assessment*. [Online] Available from: https://www.ribblevalley.gov.uk/download/downloads/id/7085/strategic_flood_risk_assessment.pdf. [Accessed: June 2020].
[10] Geotechnics. 2020. Ground Investigation for Haweswater Aqueduct Resilience Programme – TR3 Factual Report for United Utilities Limited. Project No. PN194021.

Flood Source / Assessment Element	Assessment Summary	Conclusion
the low-lying areas that define the coastline.	Therefore, no risk from this source has been identified and no further assessment is necessary.	
Fluvial Flood Risk (Main Rivers) Flooding originating from Main Rivers, including the River Hindburn and the River Hodder.	Environment Agency Flood Zone definitions are set out in the *National Planning Policy Guidance* (2014) and range from 1 to 3, with Flood Zone 1 having the lowest flood risk. The Proposed Bowland Section would be located within Flood Zone 1 except for the construction access road across the River Hodder. No other temporary or permanent above-ground crossings of Main Rivers are proposed. Construction phase discharges into the catchments of the River Hindburn and the River Hodder have the potential to increase flow and increase risk downstream and need to be considered in further detail. Discharges of groundwater ingress into the decommissioned section of the Haweswater Aqueduct into the River Hodder also need to be assessed.	Scoped in
Fluvial Flood Risk (Ordinary Watercourses) Flooding originating from minor watercourses, with localised flood risk issues.	During the enabling, construction and operational phases, features such as temporary access tracks and crossings, construction compounds and other above-ground structures such as valve house buildings would be constructed near or over Ordinary Watercourses. The scoping assessment identified that enabling and construction phase impacts were likely to be short term in duration, and could be mitigated effectively through the application of good design and construction practices. Long-term impacts to Ordinary Watercourses would be limited to small changes to rate of surface water runoff from new valve house buildings and associated infrastructure which could also be mitigated through the application of good practice. The need for further detailed assessment of fluvial flooding from Ordinary Watercourses would be considered on a case-by-case basis once additional design information is available.	Scoped in
Surface Water (Pluvial) Flooding resulting from high intensity rainfall, with runoff travelling overland and ponding in local topographic depressions before the runoff enters any watercourse, drainage systems or sewer.	During the construction phase of the Proposed Bowland Section, construction access tracks and construction compounds would be constructed near or over surface water flow paths. These features also have the potential to increase runoff and flood risk downstream if not managed appropriately. Surface water flooding would need to be assessed in further detail on a case-by-case basis to determine if detailed assessment or mitigation beyond good practice would be required.	Scoped in
Groundwater	Earthworks associated with the construction of shafts, attenuation ponds and open-cut trenches have the potential to encounter groundwater. These works	Scoped in

Flood Source / Assessment Element	Assessment Summary	Conclusion
Flooding due to a significant rise in the water table, normally as a result of prolonged and heavy rainfall over a sustained period.	therefore have the potential to allow groundwater to flood excavation areas and reach the surface.	
Failure of Water Retaining Infrastructure Flooding due to the collapse and / or failure of man-made water retaining features such as hydro-dams, water supply reservoirs, canals, flood defences structures, underground conduits, and water treatment tanks or pumping stations.	Environment Agency mapping indicates that flooding from Stocks Reservoir would flow in the direction of the proposed construction access track for the Newton-in-Bowland Compound. No canals or flood defences have been identified within the vicinity of the Proposed Bowland Section.	Scoped in for construction phase only
Failure of the existing Haweswater Aqueduct	The risk of flooding from the aqueduct itself would not be assessed, as this is an existing risk and the Proposed Bowland Section would reduce the likelihood of failure.	Scoped out
Sewer and Water Mains Flooding due to surcharging of man-made drainage systems.	United Utilities has not identified any areas of sewer flood risk close to the Proposed Bowland Section and no discharges to the public sewer network are proposed. Failure of water mains is a potential source of flooding but would be unlikely to impact this type of development. Therefore, no further assessment of these sources has been undertaken.	Scoped out
Land Drainage and Artificial Drainage Failure of land drainage infrastructure such as drains, channels and outflow pipes, which is most commonly the result of obstructions, poor maintenance and / or blockages.	No data are available on the location of local land drainage assets. Where these features are identified on site and affected, they would be replaced if necessary with assets that have the same performance. Therefore, the risk of flooding is unlikely to change, and no further assessment would be necessary.	Scoped out
Climate Change Climate change and the impacts associated with wetter winters and more intense storm events have the potential to increase flood risks.	The enabling and construction phases of the Proposed Bowland Section would be approximately seven years in duration starting in 2023. Therefore, the effects of climate change should not be considered in relation to this phase. Operational phase infrastructure would be predominantly below ground. The impact of climate change on flood risk to permanent above-ground features should be undertaken on a case-by-case basis to determine if detailed assessments would be required.	Scoped in
Existing Infrastructure Existing components of the Haweswater Aqueduct and associated operational activities.	Existing structures and associated operational activities were excluded from the scope of the assessment. These include the: ▪ Operation of existing washouts to drain the aqueduct for routine maintenance	Scoped out

Flood Source / Assessment Element	Assessment Summary	Conclusion
	▪ Existing overflows that enable discharge from the aqueduct into local watercourses in the event of a downstream blockage or collapse ▪ Existing tracks leading to valve house buildings that would be used by the Proposed Bowland Section. These structures would continue to operate as they do currently and would therefore not be affected by the Proposed Bowland Section.	

2.3.3 Scoping Phase Limitations and Assumptions

35) The scoping flood risk assessment was undertaken with the following limitations and assumptions:

- The assessment was based upon early conceptual design information that included generalised route corridors and wide areas for potential temporary works. Several key design decisions had not yet been made, such as:
  - The aqueduct construction technique (open-cut trench or tunnelling)
  - The location of enabling works including construction access track and construction compounds
  - The location of (operational phase) surface water and groundwater discharge outfalls
  - The strategy to decommission the section of the Haweswater Aqueduct to be replaced by the Proposed Bowland Section.
- The assessment was based on a qualitative review of national datasets and publicly available data only.

2.4 Main Phase Assessment

36) Given the limited potential to impact on flood risk identified during the scoping phase assessment, it was agreed with the Environment Agency and Lancashire County Council as the Local Lead Flood Authority (LLFA) that the main phase assessment would focus on the key flood risks and potential impacts that have been confirmed to be present within the assessment area ('scoped in') linked to:

- Fluvial flooding
- Surface water flooding
- Groundwater flooding
- Reservoir flooding.

37) The Proposed Bowland Section design has also developed since the scoping phase, and further design information is now available. Therefore, the assessment has also focussed on the following key high-risk or high-impact activities or features associated with the construction, operation and decommissioning of the Proposed Bowland Section including:

- Temporary construction compound sites, associated features, temporary access tracks and surface water drainage
- Construction and operation of a temporary bridge across the River Hodder
- Management of groundwater dewatered during tunnel boring construction
- Commissioning of the tunnel by flushing water through the completed tunnel
- Operation of permanent above-ground infrastructure (valve house buildings and air valves)
- Permanent discharge of groundwater from the decommissioned aqueduct.

38) Like the scoping phase assessment, the main phase has also been based upon readily available national flood risk datasets (Section 2.3.1), supplemented with hydrological and hydrogeological assessment, design information provided by United Utilities and from site walkover surveys undertaken by Jacobs during spring 2020. Where the design of assets and features of the Proposed Bowland Section was not as well developed at the time of undertaking this assessment, an assumption regarding flood mitigation will be made (see Section 2.4.2).

39) With the exception of the assessment of the temporary River Hodder crossing, no detailed hydraulic river modelling or other quantitative assessment has been undertaken. Therefore, the assessment of risk and potential scheme impacts has been determined based on a conceptual understanding of changes to flooding mechanisms. Where there was uncertainty, a precautionary approach has been taken.

2.4.1 Assessment Area

40) The definition of the assessment area for the FRA varies depending upon the source of flooding. For fluvial and surface water flooding, a 50 m buffer from the planning application boundary associated with the above-ground elements of the Proposed Bowland Section was adopted. This has been extended along watercourses or identified flow routes if there is potential for impacts further downstream. However, any features bounding the construction footprint such as roads were taken into account.

41) The assessment area for fluvial and surface water flooding did not include the route of the tunnel where there would be limited potential for interaction with flooding at the surface.

42) For groundwater flooding, the area of the construction footprint was assessed with no buffer zone applied. Given the horizontal boring method proposed, the assessment area for the assessment of groundwater flood risk does not include the route of the tunnel due to the temporary and insignificant impact to groundwater levels from the construction method for the tunnel itself. The assessment area includes all other construction activities within the red line boundary. The assessment also includes the decommissioning of the existing aqueduct due to potentially long duration impacts on groundwater flows.

2.4.2 Limitations and Assumptions

43) As is the case with many infrastructure projects of this type / scale, planning permission is sought as the basis for informing the award of a contract for undertaking detailed design and build activities. A key implication of this is that the design is limited to that sufficient to inform the EIA process and design details will come forward at the detailed design stage. To enable the level of design to be developed in sufficient detail to inform the EIA several assumptions have been made in advance of detailed design by a design and build contractor.

44) As details have emerged from the ongoing ground investigation and discussions with landowners and stakeholders some design iterations have been required to accommodate changes to these assumptions. In some areas, it would be necessary to resolve aspects of the design post determination through application of conditions requiring the Contractor (who would carry out detailed design and construction activity) to provide details for agreement with the local planning authority. It is intended that such details would be within the parameters assessed in the ES.

45) The main phase flood risk assessment has been undertaken with the following limitations and assumptions:

- The assessment is based on the design details that were available at the time of writing. Whilst the location of most infrastructure components has been confirmed, full details of vertical alignments and detailed designs were not available
- The Draft Factual GI Report available at the time of writing is not a finalised and fully checked set of data. The assessment is reliant on the accuracy of the information reported by the GI contractor at the time of writing

- Limited consultation was undertaken with Lancashire County Council (LLFA) due to the limited availability of council officers during the COVID-19 pandemic, and therefore no flood history data were provided.

46) It is assumed that in addition to embedded mitigation measures the elements of the Proposed Bowland Section that have yet to be designed in detail would be designed using appropriate flood design standards and good practices to help mitigate the flood risks and potential scheme impacts. The Construction Code of Practice (CCoP) is Appendix 3 of the ES and has been produced to provide an overview of appropriate flood design principles, standards and good practice to be considered at later stages of the design process.

3. Enabling and Construction Phase

3.1 Introduction

47) This section of the FRA focusses on both the flood risk to the Proposed Bowland Section and potential impacts on flood risk as a result of the Proposed Bowland Section during the enabling and construction phases only. In line with Section 2.4, this focusses on fluvial, surface water, groundwater and reservoir flooding associated with temporary construction compound sites, associated features, construction access tracks and surface water drainage.

48) A location-specific assessment of flood risk associated with the Proposed Bowland Section is presented in Annexe A. This includes details of the baseline flood risk, the potential effects and the likely magnitude of impacts. The section therefore provides an overview of the key findings.

3.2 Fluvial Flood Risk

49) Fluvial flooding refers to flooding from rivers, streams and other inland watercourses. Fluvial flooding is usually caused by prolonged or intense rainfall, generating high rates of runoff which overwhelm the capacity of the channel. When this occurs, excess water spills onto low-lying areas of land adjacent to the channel.

50) Fluvial flood risk can be divided between risk from Main Rivers and risk from Ordinary Watercourses. Main Rivers are usually larger rivers and streams where the Environment Agency carries out maintenance, improvement or construction work to manage flood risk. Ordinary Watercourses are any other watercourses not designated as Main Rivers.

3.2.1 Fluvial Flood Sources

51) The northern section of the Proposed Bowland Section is located within the River Hindburn catchment, which is part of the wider River Lune catchment. The southern section is within the catchment of the River Hodder. The River Hindburn and the River Hodder are both Main Rivers. The Environment Agency Flood Map for Planning (FMfP) as illustrated on Figure 2 shows the extents of Flood Zones 3 and 2. The Strategic Flood Risk Assessments (SFRA) for Lancaster City and Ribble Valley do not identify any areas of Functional Floodplain (Flood Zone 3b) associated with these Main Rivers within the development envelope of the Proposed Bowland Section.

52) The River Hindburn flows from east to west at a distance of approximately 800 m from the Lower Houses Compound. The River Hodder, by contrast, would be crossed by a temporary access track associated with the Proposed Bowland Section, although the Drive Portal within the Newton-in-Bowland Compound would be located approximately 500 m north.

53) Several Ordinary Watercourses are present within and adjacent to the Proposed Bowland Section. These Ordinary Watercourses are generally small, first- or second-order streams with small catchments that are tributaries of either the River Hindburn or the River Hodder. Existing land uses include agricultural land, isolated farm properties and the local road network.

54) These Ordinary Watercourses are not included in the Environment Agency fluvial flood mapping at the point where they pass the Proposed Bowland Section and do not have any fluvial Flood Zones defined. Therefore, the probability of flooding along these watercourses has been inferred from the Environment Agency's Risk of Flooding from Surface Water Mapping, which is presented on Figure 3. This mapping shows that flooding from these Ordinary Watercourses is generally restricted to narrow floodplains with a generally low probability of flooding (between 1 % and 0.1 % AEP) although areas of higher flood probability do exist. Although the probability of flooding is typically low the catchment characteristics, including steep topography, limited vegetation cover comprising pastoral grassland, and low permeability drift geology comprising Glacial Till or Peat[11] are typically associated with flashy flow regimes that can rise and fall very quickly, giving little warning of flooding.

[11] BGS (2020c) Onshore Geoindex. [Online] Available from: http://mapapps2.bgs.ac.uk/geoindex/home.html [Accessed: June 2020].

3.2.2 Fluvial Flood Risk to Enabling and Construction Activities

55) As noted in Table 2, fluvial flooding is not assessed along the route of the proposed tunnel as this element of the Proposed Bowland Section would be entirely below ground with no interaction with fluvial sources.

56) As shown on Figure 2, the majority of enabling work and construction activities would be located within Flood Zone 1. Therefore, the risk of flooding from Main Rivers to these activities is generally low. However, the temporary bridge across the River Hodder and the sections of access track leading to this structure would be located within Flood Zone 3 and would have a high probability of flooding.

57) All construction compounds would also be located within areas with a low probability of flooding from Ordinary Watercourses as construction activities would be remote from watercourses, as illustrated on Figure 3. The risk from each watercourse is detailed in Annexe A.

58) The proposed temporary access roads leading to both compound locations would require crossings over Ordinary Watercourses and so there would be localised areas of high risk. The temporary access road to the Lower Houses Compound would require the crossing of one watercourse (Unnamed Watercourse 169). The Environment Agency's Risk of Flooding from Surface Water Mapping has been used to infer fluvial flood risks due to lack of fluvial hydraulic model data in this area. This mapping indicates that this crossing would be at risk of flooding during the 3.33 % AEP flood event. However, the flood extent is predicted to be narrow and flood depths would be shallow (less than 300 mm).

59) The proposed temporary access road to the Newton-in-Bowland Compound would require three new crossings across Unnamed Watercourse 384, two new crossings across Unnamed Watercourse 386 and a crossing of Unnamed Watercourse 1312. Flood extents are predicted to be narrow but depths of up to 900 mm could be experienced.

60) The actual level of flood risk to the temporary access road at these locations would be dependent on upstream channel capacity and the capacity of the existing or proposed culvert crossing, which are not accurately represented in the Environment Agency's Risk of Flooding from Surface Water Mapping. As part of the construction of the access road at these locations, new culverts would be required (see Section 3.2.3), which would also influence the level of flood risk.

61) Following construction of the temporary access track and culvert, there would remain a residual risk of flooding to the road during flood events that exceed the capacity of the existing channel and new culverts. As the track in the crossing locations would run across the slope of the hillside, flood flows surcharging from the culverts would back up and spill across the road before re-entering the watercourse downstream, resulting in relatively shallow flood depths, and would continue downstream along the watercourse. As these would be important access tracks to compound sites, measures detailed within the CCoP including the monitoring of water levels and closure of roads during periods of flooding would be implemented to help manage these residual risks and impacts upon the works.

62) With these mitigation measures and a commitment to apply good practice in place, the direct risk of flooding from Ordinary Watercourses would be low and would be limited to short-term disruptions to access.

Fluvial Flood Risk to the Temporary Access Road and Bridge Crossing

63) The number of traffic movements associated with the construction phase would pose unacceptable impacts within the Village of Newton-in-Bowland and the narrow roads would make the passage of abnormal loads difficult. Therefore, a new temporary bridge across the River Hodder would be required as part of the Proposed Scheme.

64) Flood Zone mapping presented on Figure 2 and an analysis of the existing topography indicate that the extent of Flood Zone 3 in the area around the proposed bridge would be confined within a floodplain approximately 200 m wide by ground rising to the north and south. Existing land uses include agricultural land, a Wastewater Treatment Works (WwTW) located on the right (north) bank and the B6478 road, which crosses the River Hodder approximately 200 m north of the proposed bridge location via an existing masonry bridge that features a double arch with a pier within the watercourse.

65) As a detailed hydraulic model of the River Hodder was not available for this location, a new hydraulic model of the River Hodder was constructed as part of this FRA. Full details of the modelling process and results are presented in Annexe F.

66) The baseline results of this modelling indicate that during the 50 % AEP flood event, flow would exceed the capacity of the existing B6478 bridge and would back up behind the road resulting in upstream out-of-bank flooding. However, the road would not overtop and the control of peak flood flows at the bridge would mean that pass-forward flow would remain in bank immediately downstream of the structure, with no flooding predicted downstream of the B6478 during the 50 % AEP flood event. During the 20 % AEP event, flooding would be limited to a small extent along the Unnamed Watercourse 1312, which is a minor tributary within the left (south) bank floodplain.

67) During the 10 % AEP flood event, flow is predicted to spill over the B6478 into the left (south) bank floodplain resulting in flooding of up to 0.4 m deep within the fields in which the bridge and access road would be located. Flow would also start to overtop the right (north) bank during the 10 % AEP flood event with a narrow (10 m wide) flow path of up to 0.3 m deep forming.

68) Flood depths and extents would continue to increase with increasing flood magnitudes with flood depths during the 1 % AEP flood event predicted to reach 1.1 m within the left (south) bank floodplain and 0.7 m deep in the right (north) bank floodplain, which would result in flooding of the existing WwTW.

69) Flood depths along the B6478 would be relatively shallow during all modelled flood events due to the flow spilling across the road. However, this would result in high flow velocities. A summary of maximum depths, velocities and hazard classifications along the B6478 is presented in **Error! Reference source not found.**. This indicates that this road is likely to be effectively impassable during the 3.33 % AEP flood event onwards.

Table 3: Summary of baseline flood risk to the B 6478

Event Magnitude	Max. Flood Depth (m)	Max. Flood Velocity (m/s)	Flood Hazard Classification
5 % AEP	No flooding	No flooding	No flooding
10 % AEP	0.1	1.2	Low hazard
3.33 % AEP	0.3	2.3	Moderate hazard
1.33 % AEP	0.4	2.4	Moderate hazard
1 % AEP	0.5	2.8	Significant hazard

70) During the outline design stage of the Proposed Scheme, several crossing locations were considered, taking into account a range of design and environmental considerations including flood risk. The location of the proposed access road and temporary bridge crossing has been confirmed (see Figure 2).

71) The preferred option, a single-span bridge, is considered to be the best option due to the stable straight channel, the relatively narrow floodplain and its proximity to the existing road network. It would however not be practical to cross the entire floodplain in a single span. Therefore, ramps within the floodplain would be required.

72) Whilst the detailed design of the bridge has not yet been finalised, the outline design of the preferred option comprises the following features to reduce the risk of flooding and the impacts on the bridge structure elsewhere (see Section 3.2.3):

- The bridge soffit level would be set at the 1 % AEP peak flood level plus 600 mm freeboard
- Structures (e.g. piers) within the river channel would be avoided with the river being crossed in a single span from ramps located on either bank
- Flood relief culverts would be built into the ramps (4 x 1 m box culverts).

73) Construction works associated with the bridge would be at risk of flooding during events that exceed the 50 % AEP flood event, with large areas of the site inundated during events in excess of the 10 % AEP flood event. The Contractor should be aware that it would be possible for one or more significant flood event to occur within a single year, which could cause significant disruption to the works and pose a risk to workers, and as a consequence the need for mitigation measures has been identified.

74) To manage the risk to workers of flooding during the construction of the bridge a flood plan would be developed as part of the CCoP developed for the Proposed Bowland Section. This would identify that the Contractor would subscribe to the Environment Agency's Flood Warning service for the 'Upper Ribble, Hodder' Flood Warning Area. Water levels and weather forecasts would also be monitored. Proactive measures would be implemented if required, including removing workers and equipment from the floodplain prior to a flood event occurring. This plan should be supplemented by flood frequency and level information taken from the detailed hydraulic modelling undertaken prior to construction commencing. During construction of the bridge, these measures would help to manage the risk of fluvial flooding to an acceptably low level, with consequences likely to be limited to short-term (hours to days) construction programme delays.

75) Once constructed, the bridge deck would be set above the 1 % AEP peak flood level. However, the access road would be set at the existing ground level and so would also be at high risk of flooding potentially preventing access during flood events with a magnitude of 10 % AEP or greater. Mitigation measures like those employed during construction of the bridge would therefore be required and should inform the need for bridge closures prior to the onset of flooding. With these measures in place, the impacts during the construction phase of the scheme would be low and would be limited to short-term (hours to days) disruption to traffic movements to and from the compound site.

3.2.3 Fluvial Flood Risk Impacts from Enabling and Construction Activities

76) Without any mitigation, the enabling and construction phase activities assessed could potentially result in fluvial flood risk impacts associated with:

- The restriction of flood flows and loss of floodplain associated with the construction of a temporary bridge to enable the access road to cross the River Hodder
- The constriction of flood flows associated with the construction of culverts to enable the construction access road to cross Ordinary Watercourses
- Temporary increase in rates of runoff entering watercourses due to an increase in hardstanding associated with compound sites, temporary buildings and construction access tracks
- Temporary discharges of groundwater entering watercourses from excavations and tunnelling activities.

77) The risk to each watercourse affected is summarised below and detailed in Annexe A.

Impact of the Temporary River Hodder Bridge Crossing

78) Whilst the optioneering and outline design process has been carried out to reduce the impact of the temporary bridge crossing on flood risk, the preferred bridge crossing would still consist of a new structure (perpendicular to flow) within the floodplain. The new structure would act as a barrier to floodplain flow as well as reducing the volume of floodplain storage, which could have an impact of flood risk elsewhere.

79) To minimise these effects, flood mitigation measures were tested, which included single 900 mm diameter culverts within the bridge ramps and 4 x 1 m box culverts. The 4 x 1 m box culvert was shown to be most effective at reducing upstream impacts and was therefore adopted as part of the preferred design. A detailed comparison the of the bridge options is presented in Annexe E Depth difference maps for each modelled return period for the preferred option are also presented in within Annexe E.

80) Due to the relatively steep gradient of the River Hodder in this location and the difference in floodplain levels between sections upstream and downstream of the B6478, any increase in flood levels upstream of the B6478 would be minimal. With the onset of flooding controlled by the existing B6478 road and

associated bridge, there would be no change to the onset and frequency of flooding. Generally, there would be limited increase in flood extents with no additional receptors flooded.

81) However, due to the confined nature of the floodplain, the hydraulic modelling confirms that the presence of the bridge structure would still result in an increase in flood levels in the following areas:

- Agricultural land upstream of bridge in left (south) bank floodplain
- WwTW in right (north) bank floodplain
- Agricultural land downstream of bridge in right (north) bank floodplain
- The B6478.

82) The testing of the bridge options indicated that the loss of floodplain storage due to the ramps would have a negligible impact on flood risk and that it is the head loss associated with the constriction of flood flows that would be responsible for the impacts.

83) A summary of the impact on peak flood depths is presented in Table 4, with a detailed discussion of the impacts on flood risk within each area presented in the sections below.

Table 4: Summary of peak flood depth impacts

AEP Event	Location of peak flood depth change (m)			
	Agricultural Land Upstream of Bridge in Left (South) Bank Floodplain	WwTW in Right (North) Bank Floodplain	Agricultural land Downstream of Bridge in Right (North) Bank Floodplain	B6478
50 % AEP	0.00 (Not flooded)	0.00 (Not flooded)	0.00 (Not flooded)	0.00 (Not flooded)
20 % AEP	0.00 (Not flooded)	0.00 (Not flooded)	0.00 (Not flooded)	0.00 (Not flooded)
10 % AEP	+0.27	0.00 (Not flooded)	+0.10	+0.01
3.33 % AEP	+0.17	+0.11	+0.15	+0.02
1.33 % AEP	+0.21	+0.20	+0.04	+0.03
1 % AEP	+0.22	+0.20	+0.02	+0.03

84) As can be seen from Table 4, the greatest impact to peak water levels (+0.27 m) would be in the agricultural land within the left (south) bank floodplain as floodplain flow backs up behind the proposed bridge structure. Impacts would be experienced during from the 10 % AEP onwards. However, with deep (approximately 1 m during the 3.33 % AEP flood event) flooding predicted in this area during the baseline scenario, and the low sensitivity of the pastural land to flooding, the impact of these increases in flood depth is considered to be moderate.

85) The existing WwTW located immediately upstream of the bridge is only at risk of flooding during flood events with a magnitude equal to or greater than 3.33 % AEP, in contrast to other areas of floodplain where flooding would onset during the 10 % AEP flood event. Therefore, the likelihood of any potential impacts being realised during the six-year period in which the bridge would be in place is relatively low compared to the agricultural land within the floodplain. In the event that a 3.33 % AEP flood event were to occur, flood depths would increase by 0.11 m from a maximum of 0.4 m in the baseline scenario. As standard operating practices at the WwTW provide resilience to flooding the impact of this increase has been assessed to be negligible.

86) The increases in flood depth along the B6478 would be an order of magnitude lower than in the other areas described with a maximum increase of 0.03 m predicted during the 1 % AEP flood event. There would also be a minimal change to flow velocity, which would mean that the flood hazard classification would not change during any of the flood events modelled, and the current situation with regard to

access across the bridge during times of flood would also remain unchanged. Given the limited impact on flood risk and the short-term nature of this impact, it is considered to be negligible.

87) In addition to the increase in flood depths outlined in Table 4, the northern ramp of the proposed bridge is also predicted to divert flood flow further to the north compared to the baseline scenario, resulting in deeper and faster flood flow within the northern extent of the existing floodplain and a reduction in depth and velocity in areas closer to the channel. This effect would be most pronounced during the 3.33 % AEP flood event where maximum downstream increases in depth of 0.15 m are predicted. These impacts to the pastoral land in this area are considered to be moderate.

88) The new bridge could also be a location for blockages, which would further restrict flood flows. Hydraulic modelling confirms that with a blockage of the bridge that reduced the capacity by 50 %, there would be a further increase in flood depths upstream but flood extents would not increase, and no new receptors would be flooded. Such a significant blockage is considered to be highly unlikely. The existing B6478 bridge upstream would likely trap any large debris from the upper catchment before it reached the proposed temporary structure. The design of the proposed bridge, with a single span crossing and a soffit level 600 mm above the 1 % AEP flood level, would also further reduce the likelihood of blockages. The bridge would also form part of an operational construction site throughout its service life which would facilitate regular inspection and maintenance to be undertaken, reducing the risk of blockage still further.

89) Due to the moderate flood risk impacts predicted to the agricultural land and the WwTW, additional mitigation would be required (see Section 3.6).

Impact on Fluvial Flood Risk from Temporary Watercourse Crossings

90) The access road to the Lower Houses Compound would require one new culvert to be constructed across Unnamed Watercourse 169 which is a tributary of Cod Gill. The access roads constructed to the Newton-in-Bowland Compound would require three new culvert crossings of Unnamed Watercourse 384, two culverts across Unnamed Watercourse 386, and a crossing of Unnamed Watercourse 1312; these are all tributaries of the River Hodder. The probability of flooding along these watercourses is detailed in Section 3.2.2. Upstream receptors would be limited to agricultural land.

91) During the detailed design stage, and in accordance with CIRIA C786,[12] consideration of the potential impacts of a new culvert on flood risk should be considered further along with other water, environment and ecology constraints. A new culvert crossing could however increase the risk of flooding upstream of the culvert and to the proposed access road itself. Following best practices as outlined in CIRIA C786 new culverts would be sized to convey high flows to minimise this risk. A residual risk would remain from flows that exceed the capacity of the culvert, but with upstream receptors limited to agricultural land the impact of this residual risk is considered to be negligible.

Impact on Fluvial Flood Risk from Temporary Surface Water Discharges

92) In line with the NPPF, surface water management strategies have been developed for the TBM drive and reception site compounds. These are presented in Annexe C (Figures) and Annexe D (Drainage Assessments).

93) In line with this strategy, the drainage system serving the Lower Houses Compound would discharge surface water to Cod Gill via a storage lagoon that would restrict discharge rates to a maximum of 6.3 l/s. The Newton-in-Bowland drive compound would discharge water to the existing well house drain which outfalls into the River Hodder via a storage lagoon that would restrict discharge rates to a maximum of 9.7 l/s.

94) Table 5 provides a summary of the discharges of surface water. It is noted than the maximum discharge rates at all compound areas would be at the greenfield runoff rate.

[12] CIRIA (2019*) Culvert, screen and outfall manual (C786F)* [Online] Available from: https://www.ciria.org/ItemDetail?iProductCode=C786F&Category=FREEPUBS. [Accessed: June 2020].

Table 5: Summary of drainage design parameters used within the Surface Water Drainage Strategy

Compound	Receiving Watercourse	Compound Area	Qbar*	Attenuation Volume	Average Discharge from Tunnelling Activities**	Maximum Discharge Rate
Lower Houses TBM Reception Site Compound	Cod Gill (tributary of River Hindburn)	0.61 ha	6.35 l/s	481 m^3	2.5 l/s	6.3 l/s
Newton-in-Bowland TBM Drive Site Compound	River Hodder via the Well house drain	0.8 ha	9.68 l/s	568 m^3	4 l/s	9.7 l/s

* Qbar is defined the mean annual flood flow.
** Discharge at greenfield runoff rate from tunnelling activities assumed within surface water drainage strategy includes all generated flows including groundwater ingress and estimated use of potable water brought to site.

Impact on Fluvial Flood Risk from Groundwater Discharges

95) Groundwater would likely be dewatered during construction activities associated with excavations, including:

- Construction of new tunnel (drive and reception) shafts
- Tunnel boring
- Sections of open-cut trenches that would be required to join the existing aqueduct to the proposed new tunnel.

96) Groundwater extracted from the excavations would be managed in accordance with the surface water management strategies as outlined above and in Annexe C (site layout drawings) and Annexe D (drainage assessments), with any groundwater from excavations routed into lagoons for attenuation and treated before being discharged as detailed in Table 5.

97) As shown in **Error! Reference source not found.**, the maximum rate of discharge from all tunnelling activities has been estimated by United Utilities within the drainage assessment (Annexe D) to be a maximum of 4 l/s at the compound areas. However, a more detailed analysis has also been undertaken as part of the groundwater impact assessment, and is presented in Chapter 7 (Water Environment) of the ES. This more detailed assessment uses the Sichardt method as described by Preene (2000)[13] to estimate the dewatering zone of influence around the reception shaft and the tunnel. This assessment concluded the rate of dewatering at the reception compound would be less than 1 l/s whilst the discharge rate from the tunnel to the drive compound would be 1.55 l/s. Therefore, the discharge rates from tunnelling activities assumed within the drainage strategy are conservative.

98) The low rates of predicted groundwater flow from dewatering that would need to be discharged and the ability to manage and control these flows through attenuation lagoons would result in a negligible impact on flow within the receiving watercourses and on downstream flood risk.

3.3 Surface Water Flood Risk

99) Surface water runoff is defined as water flowing over the ground that has not yet entered a drainage channel or similar. It usually occurs as a result of an intense period of rainfall, which exceeds the infiltration capacity of the ground or sewer system.

[13] Preene, M. (2000) *Assessment of settlements caused by groundwater control.* Proceedings of the Institution of Civil Engineers - Geotechnical Engineering Volume 143 Issue 4, October 2000, pp. 177-190.

3.3.1 Surface Water Flood Sources

100) Areas at risk of surface water flooding have been identified from the Environment Agency's Risk of Flooding from Surface Water Mapping as presented on Figure 3. The mapping suggests that the risk of surface water flooding would be low across the Proposed Bowland Section (less than 0.1 % AEP). The only areas of high surface water flood risk identified by the mapping are associated with Ordinary Watercourses as assessed in Section 3.2.

3.3.2 Surface Water Flood Risk to Enabling and Construction Activities

101) As shown on Figure 3, the majority of enabling and construction activities would be located within areas at low risk of surface water flooding, with a probability of flooding of less than 0.1 % AEP.

102) To manage surface water runoff entering compound sites, drainage strategies have been prepared. Details of these strategies are presented in Annexe D and include compound perimeter drainage that would capture runoff from areas up-gradient and route it to infiltration trenches or to an attenuation lagoon prior to discharge. Therefore, the compounds are considered to have a low risk from surface water flooding.

103) Since the proposed surface water drainage for the compound sites would discharge to watercourses, there would be a potential indirect flood risk should discharge become limited due to high water levels within the receiving watercourse. In such a scenario, there would be a potential risk of the surface water drains surcharging resulting in localised flooding. The detailed design of the temporary outfalls from the surface water drainage system into Cod Gill and the valve house drain has not yet been completed. However, it is assumed that during the permitting stage this would be considered with the system designed appropriately so that it could operate effectively during such periods without causing local flooding. This is likely to be achieved through the positioning of the outfall invert above the peak flood level of the receiving watercourse, or by ensuring that there would be sufficient hydraulic head within the drainage system to enable effective discharge if the outfall became submerged. With this mitigation embedded into the design of the scheme, the risk to the surface water drainage system from fluvial flooding is considered to be low.

3.3.3 Impact on Surface Water Flood Risk from Enabling and Construction Activities

104) The proposed locations for the construction compound sites currently comprise agricultural land. The development of the construction compound sites and associated features would be likely to increase the area of impermeable surfaces and therefore increase the rate of surface water runoff. Uncontrolled, any increase in runoff could increase the risk of surface water flooding downstream through the surface water catchment or to the discharge location.

105) In line with the NPPF, surface water management strategies have been developed for each compound site and access track. These strategies are presented in Annexe C (site layout drawings) and Annexe D (drainage assessments) with the key parameters summarised within **Error! Reference source not found.**.

106) The proposed drainage strategies include:

- The placement of stockpiles of materials outside areas of surface water flood risk
- A system serving the compounds that would capture runoff and drain to attenuation lagoons prior to discharge to the ground or to a receiving watercourse or drain
- Water recycling within each tunnelling shaft site to be used for washdown activities, which would significantly reduce the demand for potable water and would also reduce the flow rate of generated water that has to be discharged to a watercourse.

107) The proposed surface water drainage would manage any potential increase in surface water runoff rates as a result of the Proposed Bowland Section and, as a result, the impact on surface water flood risk would be negligible.

3.4 Groundwater Flood Risk

108) Groundwater flood risk refers to either a rise in the water table or lowering of the ground level leading to an increased likelihood of flooding at the ground surface. The magnitude of the change in groundwater levels relative to the ground surface and spatial extent affected is considered for this assessment of groundwater flood risk impacts.

3.4.1 Groundwater Flood Sources

109) Groundwater is stored in both superficial aquifers, typically of Glacial Till, and underlying bedrock aquifers, as discussed in the Water Environment section of the main ES report (Chapter 7). At both the Lower Houses Compound and the Newton-in-Bowland Compound, BGS mapping and ground investigation data indicate that superficial deposits comprise Glacial Till.

110) Bedrock aquifers along the Proposed Bowland Section principally comprise the Hodder Mudstone Formation and Millstone Grit Group with a small area to the south containing the Chatburn Limestone Formation.

111) The groundwater-bearing Glacial Till is designated as a Secondary Undifferentiated aquifer by the Environment Agency and the BGS, with each bedrock formation designated as a Secondary A aquifer. This means that each of the bedrock aquifers contains permeable layers of rock capable of supporting water supplies at a local scale, with Glacial Till having the potential to store and yield limited amounts of groundwater which are potentially important to river baseflow and abstractions at a local scale only.

112) Generally, works are proposed in areas of low value agricultural land often bounded by local roads or access chambers associated with the existing aqueduct.

3.4.2 Groundwater Flood Risk to Enabling and Construction Activities

113) Groundwater level data have been provided in the draft GI data package. A full analysis of groundwater levels is provided in the Water Environment section of the ES report (Chapter 7). One borehole is located within the construction envelope of the Newton-in-Bowland Compound (T03_4B_BH003), some 58 m from the portal. The closest borehole to the Lower Houses Shaft (T03_4B_BH021), from available data, lies approximately 677 m away. Groundwater levels across the Proposed Bowland Section are generally found to range from 2.8 to 30.0 mbgl.

114) For the purposes of the assessment in understanding the extent of groundwater drawdown, groundwater levels have been conservatively assumed based on the available data to be 2.8 mbgl across the whole of the Proposed Bowland section.

115) BGS susceptibility to groundwater flooding data, presented on Figure 4, indicates that the area around the Lower Houses Compound is generally classified as having a moderate to high susceptibility to groundwater flooding with a potential for flooding of property below ground level. Smaller areas of very high susceptibility where there is potential for the emergence of groundwater at the surface are also present at the outer edges of the compound.

116) The Newton-in-Bowland Compound generally has a low susceptibility to groundwater flooding although small areas of moderate to high risk are also present. The temporary access route across the River Hodder is assessed to have a very high susceptibility to groundwater flooding. However, as this area is immediately adjacent to the River Hodder and minor tributaries, groundwater emergence is likely to be indistinguishable from fluvial flooding which is assessed in Section 3.2.2.

117) Below-ground elements of the construction and enabling works would be designed to manage groundwater ingress and so would not be vulnerable to flooding, whilst embedded mitigation such as perimeter drainage would ensure that the compounds and access roads would also have a low vulnerability to any groundwater emerging at ground level.

118) In summary, based on the GI data and BGS flooding susceptibility maps, the embedded mitigation incorporated into the design of the Proposed Bowland Section would ensure that the groundwater flood risk to enabling and construction activities would be low and no additional mitigation would be required.

3.4.3 Impact on Groundwater Flood Risk from Enabling and Construction Activities

119) Given the proposed depths of the shaft and portal excavations to 10.5 mbgl and 11 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding within the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 7.7 m and 8.2 m respectively.

120) Similarly, a drainage strategy to control groundwater ingress would apply to the following shallower excavations:

- open-cut trenches at 5 mbgl required for pipe connections and overflows
- attenuations ponds at 2 mbgl.

121) Dewatering techniques would temporarily lower the water table resulting in short-term, beneficial impacts on groundwater flooding within the vicinity of the excavations.

122) As shown in Annexe A, the majority of impacts from the proposed construction works are assessed as negligible. An exception exists for the Newton-in-Bowland Portal which is categorised as a beneficial impact of minor magnitude. However, due to the lack of vulnerable receptors and low groundwater levels in proximity to the portal, the potential impact on flood risk is negligible.

123) In terms of impact to surface water, Cod Gill watercourse lies in proximity to the Lower Houses Multi-line Connection. At the Newton-in-Bowland Compound, Unnamed Watercourses 384 and 385 would be in proximity to the connection excavation. The contribution to baseflow to these watercourses could be locally and temporarily slightly reduced. The impact of groundwater discharges to surface water is assessed within the fluvial flood risk section (section 3.2.3).

124) In summary, any adverse impacts on groundwater flood risk has been assessed to be negligible and no additional mitigation is required.

3.5 Reservoir Flood Risk

125) Reservoir failure can be a particularly dangerous form of flooding as it results in the sudden release of large volumes of water that can travel at high velocity. This can result in deep and widespread flooding, potentially resulting in significant damage. The likelihood of reservoir flooding occurring is however extremely low with all large reservoirs (over 25,000 m^3) managed in accordance with the Reservoirs Act 1975[14].

3.5.1 Reservoir Flood Sources

126) There is one large reservoir located approximately 5 km upstream of the southern extent of the Proposed Bowland Section, Stocks Reservoir, which is owned and operated by United Utilities. No smaller reservoirs (less than 25,000 m^3) have been identified.

127) The Environment Agency's online reservoir flood mapping (Figure 4) illustrates the maximum flood extents from reservoir failure along the route of the Proposed Bowland Section.

3.5.2 Reservoir Flood Risk to Enabling and Construction Activities

128) Stocks Reservoir. Environment Agency reservoir flood mapping indicates that the Newton-in-Bowland Compound would be located entirely outside the maximum extent of potential reservoir flooding. However, the failure of Stocks Reservoir would pose a risk to the access road, the temporary bridge across the River Hodder and the construction works associated with these scheme elements. Maximum flood depths of more than 2 m and maximum flow velocities of more than 2 m/s are predicted along the River Hodder in the event of a reservoir failure.

129) Failure of any reservoir would be however highly unlikely during the enabling and construction phases of the Proposed Bowland Section. Also, as the operator of Stocks Reservoir, United Utilities would be

[14] Reservoirs Act (1975) C. 23 [Online] Available from: https://www.legislation.gov.uk/ukpga/1975/23 [Accessed 22 May 2020]

able to provide advance warning of any potential dam safety issues to contractors and staff working downstream. Therefore, the risk to these works is considered to be low.

3.5.3 Impact on Reservoir Flood Risk from Enabling and Construction Activities

130) The Proposed Bowland Section would be remote from Stocks Reservoir. Therefore, no mechanism has been identified by which the Proposed Bowland Section would increase the likelihood of reservoir failure.

131) The proposed temporary bridge across the River Hodder would act as a barrier to flood flow in the unlikely event of a reservoir failure and would have the potential to increase flood levels upstream of the structure through the floodplain. However, any impact in the vicinity of the bridge would be confined by the topography of the valley and no new receptors would be likely to be affected. Increases in flood depth above the significant depths predicted in the baseline scenario would have a negligible impact on overall flood risk.

132) The impact of the enabling and construction phase activities of the Proposed Bowland Section on reservoir flooding would therefore be negligible.

3.6 Mitigation

133) Whilst the risk of flooding would be generally low, moderate impacts are predicted as a result of the temporary crossing over the River Hodder, and additional mitigation would be required. Based on the results of the hydraulic modelling, the following mitigation has been considered in this FRA:

- Floodplain compensation storage to replace the floodplain volume temporarily lost due to the bridge structures has been considered. However, as the primary mechanism for flood impacts is the head loss associated with the constriction of flow by the bridge ramps, the like-for-like replacement of displaced floodplain volume would not be effective in mitigating the impacts that are predicted and has therefore been discounted.
- The provision of floodplain storage volume above and beyond that required to simply compensate for the loss of volume due to the bridge has also been considered. However, with depth increases of Approximately 0.2 m over an area of approximately 35,000 m^2, the volume required to fully mitigate the impact of the bridge would be extremely difficult to accommodate within a confined floodplain which would be constrained further by the construction of the temporary access road. Therefore, it has been concluded that large-scale storage options would not be feasible and these have therefore been discounted. In addition, the range of impacts on land use and other environmental aspects from the creation of such storage would significantly outweigh the temporary flood risk impacts.
- Floodplain conveyance measures, including changes to floodplain levels to create a bypass channel for floodplain flow around the bridge ramps to reduce the effect of the head loss from the bridge structures, have also been considered. However, constraints including the existing WwTW and trees within the right (north) bank floodplain, and the proposed temporary access road, would also pose significant challenges to the design of an effective solution. Creation of bypass channels would also involve the loss of additional farmland from both the right and the left bank floodplains, which could be disproportionate to the scale of the temporary impacts predicted. The modelling of bridge options also indicates that any changes to floodplain conveyance would be likely to result in adverse downstream impacts. Floodplain conveyance measures have therefore been discounted.

134) With other forms of mitigation discounted, it is proposed that affected landowners would be compensated for any temporary losses or damages incurred as a direct result of the proposed works. Section 159 of the Water Industry Act 1991[15] provides the necessary statutory powers to United Utilities to undertake the proposed works, and compensation payable in accordance with Schedule 12 of the same Act would be agreed as part of this process. United Utilities has confirmed that existing operating practices at the WwTW would mitigate against the identified impact of flooding.

135) Assuming that the landowners agreed to the temporary change to flood risk on their land, the residual impact is considered to be negligible. Details of these agreements would be confirmed and presented

[15] Water Industry Act (1991) C.56. [Online] Available from: https://www.legislation.gov.uk/ukpga/1991/56/contents [Accessed 10/06/21]

as part of the environmental permit application along with detailed design drawings of the bridge and its associated structures.

4. Commissioning Phase

4.1 Introduction

136) This section of the FRA focusses on both the flood risk to the Proposed Bowland Section and potential impacts on flood risk as a result of the Proposed Bowland Section during the commissioning phase. In line with Section 2.4, this focusses on fluvial, surface water and groundwater flooding associated with the attenuation lagoons, de-chlorination equipment and the discharge of water to local watercourses.

4.2 Fluvial Flood Risk

4.2.1 Fluvial Flood Risk to Commissioning Activities

137) The exact locations of the attenuation lagoons and de-chlorination plant have not been finalised, but they would be located within the planning application boundary around the Lower Houses Compound and the Newton-in-Bowland Compound.

138) As outlined in Section 3.2, these compounds and associated features would all be located within Flood Zone 1 and therefore the risk of fluvial flooding to the attenuation lagoons and other commissioning phase activities from Main Rivers and Ordinary Watercourses would be low.

4.2.2 Fluvial Flood Risk Impacts from Commissioning Phase Activities

139) The commissioning phase of the Proposed Bowland Section would involve the discharge of water to Cod Gill in the north of the section and to the River Hodder in the south of the section. The discharge into Cod Gill would be upstream of residential property and other flood risk receptors whilst agricultural fields are present downstream of River Hodder. Since the discharge of water used to flushed away any debris from new aqueduct would not be associated with the existing catchment of the receiving watercourses, this would have the potential to result in an increase in flood risk downstream.

140) Prior to discharge to the watercourses, the proposal would be to attenuate the water using lagoons and discharge via the same drainage outfall linked to the proposed surface water drainage system serving the Lower Houses and Newton-in-Bowland construction compounds. The discharge rates would be attenuated to a maximum of 25 l/s, with continuous discharge lasting for approximately two to three weeks.

141) To assess the potential impact of the commissioning discharges into the River Hodder, a comparison has been made to QMED[16] and Q10[17] predicted flow rates at the discharge location within the River Hodder as presented in Table 6.

Table 6: Comparison of flows within the River Hodder to the commissioning flows

Commissioning Maximum Flows (m^3/s)	Peak Flow Estimate River Hodder (m^3/s)	
	Q10	QMED
	9.66	75.6
0.025	+0.03 %	+0.26 %

142) Table 6 shows that even the maximum estimated discharge from the commissioning flows would be a negligible contribution to the QMED flow in the River Hodder (less than 1 % of QMED flows). The additional contribution of flow would also not be enough to increase the Q10 flow to the point where it could be considered a flood flow. Given the negligible contribution that discharges from the

[16] QMED is the median of the annual maximum flow series which is equivalent to the 50 % AEP event and is used as an approximation of bankfull flow.
[17] Q10 is the 90-percentile flow or the flow equalled or exceeded for 10 % of the flow record.

commissioning flows would make to fluvial flood flows within the River Hodder, the impact on flood risk downstream of the Proposed Bowland Section is also considered to be negligible.

143) Data on dry weather and flood flow rates within Cod Gill, which would receive commissioning flows in the north of the Proposed Bowland Section, and any information on the capacity of any key pinch points such as culvert crossings were not made available at the time of writing this FRA. Although the discharge would be attenuated and very short in duration, it is not possible to assess the actual impact that these discharges would have on flood risk downstream. It is therefore assumed that the impact to receptors along Cod Gill would be moderate and that additional mitigation would be required (see Section 4.5).

4.3 Surface Water Flood Risk

4.3.1 Surface Water Flood Risk to Commissioning Activities

144) As outlined in Section 3.3, the compound locations where the attenuation lagoons and de-chlorination plant would be located are at low risk of surface water flooding (less than 0.1 % AEP). Therefore, the risk to commissioning activities from surface water would be low.

145) The attenuation lagoons would however be new, open, raised structures and would be a new source of potential flooding in the event that they overtop or fail. It is assumed that as new open structures, they would collect direct rainfall. It is expected that this would be taken into account during the detailed design of the structure and either additional capacity (freeboard) provided or a process developed to make available the necessary capacity once the flushing process begins. With this additional freeboard and management, the risk of overtopping is low. Since these would also be new structures, the risk of failure would also be low.

4.3.2 Surface Water Flood Impacts from Commissioning Activities

146) Large lagoons would also have the potential to divert surface water flowpaths. However, the lagoons would be located within areas with a low risk of surface water flooding and therefore the impact on the diversion of flows would be negligible.

4.4 Groundwater Flood Risk

147) None of the commissioning activities would require any excavations or below-ground structures which would intercept groundwater. None of the commissioning activities would involve a discharge to ground. Therefore, no mechanism by which groundwater flooding would be altered has been identified and the impact on this source of flood risk is assessed to be negligible.

4.5 Mitigation

148) Additional mitigation would be needed to address the potential impact on fluvial flooding from the discharge of water to Cod Gill.

149) It is understood that mitigation measures would be likely to include:

- Further detailed analysis to assess the actual level of flood risk impacts to the receiving watercourse and receptors downstream to determine appropriate discharge rates; for example, to the determine trigger levels at which there would be a risk of flooding downstream such as bank levels or the soffit levels of downstream watercourse crossings
- Design changes to restrict maximum discharge rates and / or monitoring of downstream water levels and a system in place to restrict discharges during high water levels in the receiving watercourse.

5. Operational Phase

5.1 Introduction

150) This section of the FRA focusses on both the flood risk to the Proposed Bowland Section and potential impacts on flood risk as a result of the Proposed Bowland Section during the operational phase. In line with Section 2.4, this focusses on fluvial, surface water and groundwater flooding associated permanent above-ground infrastructure, which would comprise new valve house buildings with associated hardstanding and air valves. The operational phase of the Proposed Bowland Section is not predicted to have any impact on reservoir flooding and is not considered further.

5.2 Fluvial Flood Risk

5.2.1 Fluvial Flood Risk to Operational Activities

151) All permanent infrastructure, including above-ground installations, associated with the operational activities would be located within Flood Zone 1. Therefore, the risk of flooding from Main Rivers to operational activities would be low. All permanent above-ground infrastructure including valve house buildings would also be located in areas that are at low risk of fluvial flooding from any Ordinary Watercourses, as inferred from the Risk of Flooding from Surface Water Map.

5.2.2 Impact on Fluvial Flood Risk from Operational Activities

152) Without mitigation, operational phase activities assessed could potentially result in fluvial flood risk impacts associated with permanent increase in rates of runoff entering watercourses due to an increase in hardstanding associated with new valve house buildings.

153) The existing valve house buildings would be retained at each compound to facilitate access to the decommissioned aqueduct. The two new valve house buildings located one at each end of the Proposed Bowland Section would result in an increase in impermeable area. Operational access to these buildings would be via the existing access roads. There are currently no proposals for the management of surface water runoff from these features. However, it is assumed that a drainage system would be designed that would follow the drainage hierarchy with water discharged to the ground where possible. If infiltration drainage were not possible, runoff would be attenuated prior to discharge to watercourse at greenfield runoff rates. On this basis, the impact on fluvial flood risk would be negligible.

5.3 Surface Water Flood Risk

5.3.1 Surface Water Flood Risk to Operational Activities

154) All permanent infrastructure, including above-ground installations, associated with the operational activities would be located within areas at low risk of surface water flooding, with a probability of flooding of less than 0.1 % AEP.

5.3.2 Impact on Surface Water Flood Risk from Operational Activities

155) The proposed locations for the new valve house buildings located one at each end of the Proposed Bowland Section are existing greenfield sites currently comprising grassland. Each of the permanent valve house buildings would increase the area of impermeable surfaces by approximately 200 m^2 and would therefore increase the rate of surface water runoff. Uncontrolled, any increase in runoff could increase the risk of surface water flooding downstream through the surface water catchment.

156) At the time of preparing this FRA, no surface water management strategies have been prepared for the permanent valve house buildings. It is however assumed that surface water management strategies would be developed post planning and would follow the same principles as those outlined in Annexe D, whereby surface water would be discharged to the ground as a first preference.

157) As these would be permanent features, it would be expected that the drainage design would incorporate the impacts of climate change and, as a result, the impacts on surface water flood risk would be negligible over the design life of the Proposed Bowland Section.

5.4 Groundwater Flood Risks

5.4.1 Groundwater Flood Risk to Operational Activities

158) Permanent infrastructure, including above-ground installations, associated with the operational activities within the Lower Houses Compound would be located within an area with a moderate to high susceptibility to groundwater flooding.

159) In both locations additional ground and groundwater site characterisation would be obtained. Following detailed site characterisation, any mitigation associated with controlling groundwater conditions, if required, would be embedded into the design of these buildings to ensure that they would be safe from flooding for the life of the Proposed Bowland Section.

160) Therefore, whilst the baseline risk to the valve house building at the Lower Houses Compound is high, based on BGS data, it is assumed that the risk to the valve house building with its embedded mitigation would be low, and no additional mitigation is required.

5.4.2 Impacts on Groundwater Flood Risk arising from Operational Activities

161) Proposed subsurface structures remaining in place post construction including backfill could locally disturb groundwater flows. Permanent structures have the potential to locally raise groundwater levels on the up hydraulic gradient side, and backfilled trenches with gravel materials have the potential to act as a localised drain for groundwater, locally reducing groundwater levels.

162) All operational impacts are assessed as negligible as shown in Annexe A. Potential impacts identified which include shafts acting as barriers to groundwater flow; and backfilled trenches and reinstated attenuation ponds acting as localised drains for groundwater.

163) Although the backfilled open-cut trenches would have a small positive effect on groundwater flooding, they would have a detrimental effect on a groundwater-dependent terrestrial ecosystem at the Newton-in-Bowland Compound and for this reason Chapter 7 (Water Environment) of the ES has identified that clay bunds would be required to prevent groundwater movement through the backfilled trench. This would not alter the impact of negligible on groundwater flooding at this location.

5.5 Mitigation

164) Due to the low risk of flooding being present, the mitigation embedded into the design of the operational phase activities associated with the Proposed Bowland Section is considered sufficient. Therefore, the Proposed Bowland Section would be safe from flooding and is considered not to increase flood risk elsewhere; as a result, no additional mitigation requirements have been identified.

6. Decommissioning Phase

6.1 Introduction

165) This section of the FRA focusses on the potential impacts on flood risk as a result of the decommissioning of the existing aqueduct in the Proposed Bowland Section and the ongoing discharge of groundwater ingress into the River Hodder. This section focusses on fluvial flood risk impacts only as no other flood sources would be affected.

6.2 Fluvial Flood Risk

6.2.1 Impact on Fluvial Flood Risk from Decommissioning Activities

166) As part of the Proposed Bowland Section, the existing section of aqueduct would be decommissioned. This section of the Haweswater Aqueduct showed signs of groundwater ingress occurring during condition assessments carried out in 2016. The proposed strategy to manage this ingress of groundwater would be to allow it to flow into the River Hodder via the existing overflow structure.

167) Using observed data and a Monte Carlo analysis, United Utilities has estimated the rate of groundwater ingress into the decommissioned aqueduct up to the year 2055, as presented in **Error! Reference source not found.**. Future uncertainties have limited the ability to provide a realistic forecast beyond 2055. United Utilities would continue to monitor the tunnel condition.

168) To assess the potential impact of these groundwater discharges from the decommissioned Haweswater Aqueduct into the River Hodder, a comparison has been made to QMED and Q10 predicted flow rates at the discharge location within the River Hodder, as presented in Table 7.

Table 7: Comparison of groundwater discharge and peak flows within the River Hodder

River Hodder Peak Flow		Groundwater Discharge Estimate for 2055		Percentage Increase in Peak Flow	
		Mean	Maximum	Mean	Maximum
Q10	9.66 m^3/s	0.0075 m^3/s	0.159 m^3/s	+0.78 %	+1.64 %
QMED	75.6 m^3/s	0.0075 m^3/s	0.159 m^3/s	+0.1 %	+0.21 %

169) Table 7 shows that even the maximum estimated discharge from the decommissioned aqueduct would be a negligible contribution to the QMED flow in River Hodder (less than 1 % of QMED flows). The additional contribution of flow would also not be enough to increase the Q10 flow to the point where it could be considered as flood flow.

170) Given the negligible contribution that discharges from the decommissioned aqueduct would make to fluvial flood flows, the impact on flood risk downstream of the Proposed Bowland Section is also considered to be negligible.

6.3 Groundwater Flood Risks

6.3.1 Impacts on Groundwater Flood Risk Arising from Decommissioning Activities

171) Once the new aqueduct became operational, the existing aqueduct would be decommissioned but would remain in place. Ingress of groundwater into the existing aqueduct would occur over time, representing a small dewatering rate, as detailed in Section 6.2. This would be expected to generate a small, long-term groundwater drawdown over the length of the aqueduct.

172) Whilst the existing aqueduct would drain some groundwater, decommissioning of the existing aqueduct would not be expected to generate any significant impacts to groundwater flooding due to the relatively small rate of inflow to the tunnel and associated drawdown at the aquifer scale. Therefore, the impact has been assessed as negligible.

6.4 Mitigation

173) Due to the negligible impact on flood risk associated with the decommissioning of the existing aqueduct, no additional mitigation requirements have been identified.

7. Summary and Conclusion

7.1 Summary

174) This FRA has been prepared to support the planning application for the Proposed Bowland Section of the Haweswater Aqueduct Resilience Programme, which would be located at the central section of the aqueduct. This extends from Lower Houses, 4 km south east of Wray, to the Hodder North Well, 0.5 km west of Newton-in-Bowland.

175) This FRA has been carried out in accordance with the NPPF and its PPG. Complying with planning policy would promote a scheme that would be appropriate given the level of local flood risks, would be safe during the construction and operational phases of its lifetime, and would not increase flood risk both on site and elsewhere. It has been carried out in combination with the Proposed Bowland Section design development through the EIA process and informs Chapter 8 (Flood Risk) of the ES.

176) The Proposed Bowland Section would be classified as 'water transmission infrastructure' and is therefore considered within the NPPF to be a 'water-compatible development' that is suitable in all areas of flood risk providing that it would be safe, could operate in times of flood and would not increase flood risk elsewhere.

177) Given the generally low levels of flood risk identified during the scoping phase assessment, this FRA focusses on the key flood risks and potential impacts that have been confirmed to be present within the study area: fluvial, surface water, groundwater and reservoir flooding.

178) For most of the length of the replacement aqueduct, there would be no permanent above-ground structures with a large portion of the new section of aqueduct being located deep below ground level. The assessment therefore focusses on the following key high-risk or high-impact activities or features associated with the construction and operation of the Proposed Bowland Section, in addition to the decommissioning of the existing aqueduct, including:

- Temporary compound sites, associated features, construction access tracks and surface water drainage associated with the enabling and construction phase
- A temporary crossing over the River Hodder
- Management of groundwater intercepted during excavation works including construction of the shafts, tunnelling and the open-cut trenches to connect the new tunnel to the existing aqueduct
- The commissioning of the proposed tunnel by flushing the section through with potable water that would be discharged to local watercourses
- The operation of permanent above-ground infrastructure (valve house buildings and air valves)
- Permanent discharge of groundwater from the decommissioned aqueduct.

179) Using readily available national flood risk datasets, the FRA concludes that the level of flood risk to the Proposed Bowland Section would be low from all sources of flooding except for the temporary access road and associated bridge across the River Hodder which would be in an area of high risk. The other proposed assets and activities would be generally located away from areas of high flood risk, in Flood Zone 1 and in areas with a low probability of flooding from other sources.

180) The main impact on flood risk would be associated with the temporary crossing of the River Hodder. Hydraulic modelling indicates that there would be a moderate impact on agricultural land both upstream and downstream of the proposed bridge whilst the impact to the B6478 would be negligible. Additional mitigation measures have been considered. With compensatory flood storage and floodplain conveyance-based solutions discounted due to lack of benefit and disproportionate impacts, it is proposed that landowners would be compensated for any temporary losses or damages incurred as a direct result of the proposed works. Section 159 of the Water Industry Act 1991 provides the necessary statutory powers to United Utilities to undertake the proposed works, and compensation payable in accordance with Schedule 12 of the same Act would be agreed as part of this process.

181) Other impacts identified are associated with the commissioning discharges. Whilst a hydrological analysis has been undertaken to confirm that these would have a negligible impact on the River Hodder, further assessment would be required to confirm that commissioning phase discharges to Cod Gill could be managed without increasing the risk of flooding to receptors downstream.

182) Following the groundwater flooding assessment, no significant groundwater flooding impacts would be expected.

183) **Error! Reference source not found.** provides a summary of flood risk assessment.

Table 8: Flood risk assessment summary

Phase	Flood Assessment	Fluvial	Surface Water	Groundwater	Reservoir
Enabling and Construction	Flood Risks	High	Low	Low	Low
	Flood Risk Impacts	Moderate	Negligible	Minor (beneficial)	Negligible
	Additional Mitigation	Yes	No	No	No
Commissioning	Flood Risks	Low	Low	Not applicable	Low
	Flood Risk Impacts	Moderate	Negligible	Not applicable	Negligible
	Additional Mitigation	Yes	No	Not applicable	No
Operation	Flood Risks	Low	TBC	Low	Low
	Flood Risk Impacts	Negligible	Negligible	Negligible	Negligible
	Additional Mitigation	No	No	No	No
Decommissioning	Flood Risk Impacts	Negligible	Not applicable	Minor (beneficial)	Not applicable
	Additional Mitigation	No	Not applicable	No	Not applicable

184) A key assumption of this assessment is that, in addition to embedded mitigation measures, the elements of the Proposed Bowland Section that have not yet been designed in detail would be designed using appropriate flood design standards and good practices (referred to as embedded mitigation) to mitigate the flood risks and potential scheme impacts. The CCoP has been produced to provide an overview of appropriate flood design principles, standards and good practice to be considered at later stages of the design process. .

7.2 Cumulative Impacts

185) As identified in Section 1.2, the Proposed Bowland Section would be part of a wider project to replace the existing tunnelled sections of the Haweswater Aqueduct. Therefore, consideration has been given to the potential for multiple project sections of the wider Haweswater Aqueduct Resilience Programme to have a cumulative impact on flood risk.

186) Discharges into the Lune catchment from the northern part of the Proposed Bowland Section would be limited to construction phase discharges from the Lower Houses TBM Reception Site Compound and potential operational discharges of surface water runoff from the proposed valve house building at this location. This FRA has concluded that the attenuation of all surface water and groundwater discharges into the Lune catchment would result in a negligible impact on runoff rates within the receiving watercourses.

187) In addition to discharges into the Lune from the Proposed Bowland Section, the Proposed Swarther Section of the Haweswater Aqueduct Resilience Programme would involve temporary and permanent discharges into the River Lune. However, these discharges are also considered to have a negligible impact on flood risk. The confluence of the River Hindburn and the River Lune would be more than 7 km downstream from the discharge point of either proposed section. Therefore, the cumulative impacts of the two project sections are considered to be negligible.

188) The River Hodder is part of the wider River Ribble catchment which would receive construction phase discharges from the Proposed Marl Hill Section and the Proposed Haslingden and Walmersley Section of the Proposed Programme of Works. Operational discharges of groundwater from the Proposed Marl Hill Section would also discharge into the River Ribble catchment. However, the impact of all these discharges on local watercourses has been assessed to be negligible. Therefore, the cumulative impact on the wider Ribble catchment is also considered to be negligible.

189) None of the developments identified within 5 km of the Proposed Bowland Section would be likely to cause a cumulative effect on the groundwater environment.

7.3 Conclusion

190) In conclusion, based on the assumption that embedded mitigation would be effectively designed and implemented, and that good practice is applied to the design and construction of scheme components not yet designed, the Proposed Bowland Section has been assessed to have a low risk of flooding and would have a generally negligible impact on the risk of flooding elsewhere. However, additional mitigation would be required in relation to the predicted adverse impacts from the River Hodder crossing and from commissioning phase discharges into Cod Gill.

191) Assuming that landowner agreements to mitigate the impacts of the River Hodder crossing are secured, and further assessment and mitigation is undertaken to make sure that commissioning phase discharges to watercourses would be managed effectively, the Proposed Bowland Section has been assessed to have a low risk of flooding and would have a negligible impact on the risk of flooding elsewhere. Therefore, it would comply with the requirements of the NPPF and with the requirements of local planning policies and guidance.

Annexe A: Flood Risk Assessment Tables

Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

Environmental Statement

Volume 4

Appendix 8.1: Flood Risk Assessment

Annexe A Flood Risk Assessment Tables

June 2021

Haweswater Aqueduct Resilience Programme – Proposed Bowland Section

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Jacobs U.K. Limited

5 First Street
Manchester
M15 4GU
+44(0)161.235.6000
+44(0)161.235.6001
www.jacobs.com

Flood Risk Assessment Tables

1. Fluvial flood risk – Enabling and Construction Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Cod Gill	Ordinary Watercourse (tributary of the River Hindburn)	Lower Houses TBM Reception Site Compound would be approximately 50 m east of Cod Gill. A section of open cut trench to connect the proposed tunnel to the existing aqueduct, would be approximately 20 m to the east of Cod Gill. A proposed access road from an unclassified road to the Lower Houses TBM Reception Compound would run through the catchment, broadly	**High**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. The surrounding land is agricultural. Lower House Farm is adjacent to Cod Gill downstream of the Proposed Scheme but is outside of its predicted flood extents.		The proposed Lower Houses TBM Reception Site Compound, associated access track and the landscaping area is at low risk of fluvial flooding from this watercourse and no watercourse crossings are proposed. Therefore, the main potential impact would be from changes in surface water runoff and discharges of groundwater from excavations increasing flow within the watercourse. Construction compounds have the potential to increase surface water runoff due to an increase in impermeable surfaces. These activities have the potential to increase runoff rates entering Cod Gill and the risk of fluvial flooding to Lower Houses Farm downstream. Surface water runoff from the proposed TBM Reception Site Compound would however be captured and attenuated within a storage lagoon prior to discharge into Cod Gill at greenfield runoff rates. The attenuation of runoff would ensure that there would be a negligible increase in peak flows in this watercourse and that the magnitude of effects on flood risk would be **negligible**.	Neutral
						Construction of the temporary access road would increase the area of impermeable surfaces within the catchment which would have the potential to increase surface water runoff rates into this watercourse. However, whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that general embedded mitigation will be implemented including the use of roadside drainage to capture and attenuate any increase in runoff rate to ensure that the impact on flood risk would be **negligible.**	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		parallel to Cod Gill at a minimum distance of 30 m to the east. The temporary outfall from the compound discharges into this watercourse.				Deep excavations during the construction phase within and adjacent to the compound include the TBM reception shaft and an open cut trench to connect the new tunnel to the existing aqueduct. Groundwater intercepted during construction would be discharged into Cod Gill via the storage lagoon and treatment plant used to manage surface water runoff. Groundwater flows are predicted to be less than 1 l/s and the attenuation of these flows through the storage lagoon would ensure that the impact on fluvial flood risk downstream of the discharge location would be **negligible.**	Neutral
Unnamed Watercourse 169 Ordinary Watercourse (tributary of Cod Gill)		The temporary access road between Lower Houses TBM Reception Site Compound and an existing unclassified road would cross watercourse 169. It is assumed that this crossing would require a new culvert that would be immediately downstream of an existing culvert crossing that provides field access.	**High** Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. The surrounding land is agricultural.			The proposed, temporary access road would be at low risk of fluvial flooding except for where it crosses Unnamed Watercourse 169 and its narrow floodplain. It is assumed that a new culvert would be required at this location downstream an existing culvert crossing that provides field access. Outline designs for the proposed crossing are not currently available. However, the installation of a new watercourse crossing has the potential to constrict flood flows potentially increasing flood risk upstream. Any alterations to the existing culvert providing field access has the potential to increase pass forward flow increasing fluvial flood risk downstream or constrict flow, increasing fluvial flood risk upstream. However, the detailed design of the new culvert in accordance with CIRIA C786 would ensure that the flow regime would not be adversely affected and that impacts on flood risk upstream and downstream would be **negligible**.	Neutral
						Construction of the new, temporary access road would increase the area of impermeable surfaces within the catchment of Unnamed Watercourse 169, which would have the potential to increase surface water runoff rates into it. However, whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that general embedded mitigation will be implemented including the use of roadside drainage would attenuate any increase in runoff rate to ensure that the impact on flood risk would be **negligible.**	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Unnamed Watercourse 163	Ordinary Watercourse (tributary of the River Hindburn)	Lower Houses TBM Reception Site Compound and Access Road would be located approximately 40 m west of this watercourse. Topsoil stripped from the site of the compound would be stockpiled approximately 10 m west of the watercourse immediately east of the compound.	**High**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. The surrounding land is agricultural.		The proposed Lower Houses TBM Reception Site Compound and the associated soil storage area is at low risk of fluvial flooding from this watercourse and no watercourse crossings or discharges are proposed. Therefore, the main potential impact would be from changes in surface water runoff increasing flow within the watercourse. Construction compound sites have the potential to increase surface water runoff due to an increase in impermeable surfaces. These activities have the potential to increase runoff rates entering Unnamed Watercourse 163. Surface water runoff from the proposed TBM Reception Site Compound would however be captured and attenuated within a storage lagoon prior to discharge into Cod Gill at a maximum rate of 6 l/s. Therefore, a negligible impact from runoff from the compound area is predicted in Unnamed Watercourse 163. Good practice material management measures which could include covering and re-vegetation of the soil storage area would ensure that there was no increase in runoff rates from this area and therefore the magnitude of changes in fluvial flow and flood risk within Watercourse 163 would be **negligible**.	Neutral
Unnamed Watercourse 385 and 384	Ordinary Watercourse (Tributary of the River Hodder)	The Newton-in-Bowland TBM Drive Site compound including the TBM launch portal, would be approximately 60 m north (upgradient) and would discharge into the watercourse. Temporary access roads would cross	**High**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. The surrounding land is agricultural and an existing unclassified road between		The proposed Newton-in-Bowland TBM Drive Site compound and the associated soil storage area and logistics compound are at low risk of fluvial flooding from this watercourse. Therefore, the main potential impacts would be from changes in surface water runoff and discharges of groundwater increasing flow within the watercourse, and the potential constriction of the watercourse by new crossings. Construction compound sites have the potential to increase surface water runoff due to an increase in impermeable surfaces and/or the installation of drainage systems. These activities have the potential to increase runoff rates entering Unnamed Watercourse 385. Surface water runoff from the proposed TBM Drive Site Compound and the access road would however be captured and attenuated within a storage lagoon prior to discharge into the River Hodder via the existing well house	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		the watercourse at three locations. A soil storage area and logistics compound would be approximately 10 m south of the watercourse.		Newton-in-Bowland and Dunsop Bridge runs between the TBM Portal compound and the logistics compound and crosses the watercourse.		drain at greenfield runoff rate (10 l/s). Therefore, the impact that runoff from the Drive Site compound would have on flood risk along Unnamed Watercourse 385 would be **negligible**.	
						Deep excavations during the construction phase within and adjacent to the compound include the TBM drive portal and an open cut trench to connect the new tunnel to the existing aqueduct. Groundwater intercepted during construction would be discharged into the River Hodder via the existing well house drain following attenuation within the storage lagoon and treatment plant used to manage surface water runoff. Groundwater flows are predicted to be less than 2 l/s and the attenuation of these flows through the storage lagoon would ensure that the impact on fluvial flood risk downstream of the discharge location would be **negligible.**	Neutral
						The installation of the three culverts required to support the new access road watercourse crossings have the potential to constrict flood flows potentially increasing flood risk upstream. However, the design of the new culverts in accordance with CIRIA C786 would ensure that the flow regime would not be adversely affected and that impacts on flood risk upstream and downstream would be **negligible**.	Neutral
Unnamed Watercourse 391	Ordinary Watercourse Site observations indicate that whilst it has been mapped as a watercourse it is better described as a boundary ditch.	The Access Road from the B6478 to the TBM Drive Site compound would run downstream of this ditch but would not cross it.	**Low**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is less than 0.1% AEP. The surrounding land is agricultural.		The proposed access road is at low risk from fluvial flooding associated with Unnamed Watercourse 391 which is noted to be a field boundary ditch that ends upstream of the proposed access road. There would be no discharge of surface water into the ditch and no crossing is proposed. Therefore, no potential effects from the track on this watercourse have been identified and the magnitude of any effects is assumed to be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Unnamed Watercourse 386	Ordinary Watercourse (tributary of the River Hodder)	The Access Road from the B6478 to the TBM Drive Site compound would cross this watercourse at two locations via new culverts.	**High**	Watercourse located within the floodplain (Flood Zone 2) associated with the River Hodder 200 m to the south. Fluvial flood risk from 386 is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP.		The new access road in this location would be at risk of fluvial flooding at the crossing locations. However, as it is assumed that the road would be constructed at ground level, impacts on flood risk would be limited to constriction of the watercourse due to the new culverts and increased surface water runoff rates discharged into the watercourse. The installation of the two culverts required to enable the access road crossings have the potential to constrict flood flows increasing flood risk upstream. However, the design of the new culvert in accordance with CIRIA C786 would ensure that the flow regime would not be adversely affected and that impacts on flood risk upstream and downstream would be **negligible**.	Neutral
						Construction of an access road would increase the area of impermeable surfaces within the catchment, which would have the potential to increase surface water runoff rates entering the watercourse. However, whilst a detailed surface water drainage strategy for the access road has not yet been finalised, it is assumed that general embedded mitigation will be implemented including the use of roadside drainage that would attenuate any increase in runoff rate and that the impact on flood risk within Unnamed Watercourse 386 would be **negligible.**	Neutral
River Hodder	Main River	Access road would run through the floodplain of this river and a temporary bridge crossing would be constructed immediately south of the existing waste water treatment works.	**High**	Flood Zone 3 Flood Zone mapping and an analysis of the existing topography indicates that the floodplain in this area would be confined within a floodplain approximately 200 m wide by high ground to the north and south.		At outline design stage, the location of the proposed access road and temporary bridge crossing has been confirmed. Two key flood design principles have also been established to inform the detail design process, including: ▪ The soffit level would be above the peak 1 % AEP flood level plus 600 mm freeboard; and ▪ There would be no structures (e.g. piers) within the river channel. However, at this stage it is noted that due to the width of the floodplain, abutments or piers within the floodplain would be required. Due to the confined nature of the floodplain, a new structure perpendicular to the floodplain would act as a barrier to floodplain flow and reduce the volume	Moderate /Large

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		A soil storage mound would be constructed to the south of the track on the north side of the river.		Existing land use includes agricultural land and a waste water treatment works (WwTW) located on the right (north) bank and the B6478 which crosses the River Hodder approximately 200 m north of the proposed bridge location via an existing masonry bridge which has a double arch and a pier within the channel of the River Hodder.		of floodplain storage. This would result in an increase in flood levels upstream of the crossing during a flood event that exceeds channel capacity. Any increase in peak flood levels would however be limited to the agricultural land (already located in the floodplain) and the WwTW. The existing B6478 river crossing would also likely be impacted; however, due to the relatively steep gradient of the River Hodder in this location and the difference in floodplain levels between sections upstream and downstream of the road, any increase in flood levels along the road are likely to be minimal. Increases in flood extent are not considered to be likely due to the confined nature of the floodplain. The bridge crossing is also not expected to change the frequency of flooding due to upstream controls including the B6478 and the existing upstream bridge likely to restrict flood flows and determine the onset of flooding to the area downstream by acting as a spill for flow accumulating upstream. As part of the detail design process and environmental permitting process, detail hydraulic modelling will be undertaken in consultation with the EA to assess actual flood risk impacts. It is likely that mitigation measures beyond the key design principles already stated above will be considered. These measures would include flood relief culverts through any embankments, floodplain compensation storage and landowner agreements. However, it is likely that this mitigation would not be enough to reduce the upstream flood depth increase to negligible levels and a residual impact would remain. Based on these assumed impacts, and the temporary nature of the structure, the magnitude of the adverse impacts is likely to be **moderate.** Therefore, additional mitigation would be required.	
						Construction of the access road would increase the area of impermeable surfaces within the River Hodder catchment and floodplain, which would have the potential to increase surface water runoff rates into this watercourse. However, whilst the surface water drainage strategy for the access road has not	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
					yet been finalised, it is assumed that general embedded mitigation will be implemented including the use of roadside drainage would attenuate any increase in runoff rate and that the impact on fluvial flood risk would be **negligible.**		
					The proposed temporary soil storage mound would be located within Flood Zone 2. Therefore, there would be no impact on flows or floodplain volume during events of 1% AEP or less. Therefore, the impact of this activity on fluvial flood risk is considered to be **negligible**.		Neutral
Unnamed Watercourse 1312	Ordinary Watercourse	Access Road between the B6478 and the TBM Drive Site compound would cross this watercourse via a new culvert.	**High**	Flood Zone 3 (associated with the River Hodder) Fluvial flood risk associated with Watercourse 1312 is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. Land use is agricultural.	The new access road in this location would be at risk of fluvial flooding at the crossing location. However, as it would be constructed at ground level, impacts on flood risk would be limited to constriction of the watercourse due to the new culvert and increased surface water runoff rates into the watercourse. The installation of the culvert required to enable the access road crossing has the potential to constrict flood flows potentially increasing flood risk upstream. However, the design of the new culvert in accordance with CIRIA C786 would ensure that the flow regime would not be adversely affected and that impacts on flood risk upstream and downstream would be **negligible**.		Neutral
Waddington Brook (Ordinary Watercourse)	Tributary of the River Ribble (Main River)	Disposal of tunnel arisings within Waddington Fell Quarry. The quarry is approximately 50 m to the west of the Brook at the closest point.	**High**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP.	Disposal of material within the quarry would be undertaken in accordance with the licence conditions imposed on the quarry operator and any flood risk impacts would be the responsibility of the quarry operator to assess and manage.		

2. Other sources of flood risk – Enabling and Construction Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Surface water flooding in the vicinity of the Lower Houses TBM Reception site compound		Lower Houses TBM Reception site compound and the temporary access road.	**Low**	The Flood Map for Surface Water indicates that the general probability of surface water flooding across the catchment is low (less than 0.1% AEP). However, areas of higher risk do exist, but these are associated with watercourses and are assessed under the fluvial flood risk section.		According to the Flood Map for Surface Water, the proposed Lower Houses TBM Reception site compound area is at low risk of surface water flooding. Due to an increase in impermeable surfaces, the proposed construction sites and access road have the potential to increase surface water runoff during an extreme rainfall event, and therefore increasing the risk of flooding downstream to Lower Houses Farm. Surface water runoff from the proposed compound would however be captured and attenuated by a surface water drainage system. The system serving the TBM Reception compound area would discharge at a controlled rate to Cod Gill via a storage lagoon. Whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that the use of roadside drainage would attenuate any increase in runoff rate prior to discharge. The impact on local surface water flood risk would therefore be **negligible**.	Neutral
Surface water flooding in the vicinity of the Newton-in-Bowland TBM Drive site compound		Newton-in-Bowland TBM Drive site compound and temporary access road.	**Low**	The Flood Map for Surface Water indicates that the general the probability of surface water flooding across the catchment is low (less than 0.1% AEP). However, there are localised areas along the existing access track and on the Newton to Dunsop Bridge road which would flood up to a maximum depth of 300 mm during a 1% AEP rainfall event.		According to the Flood Map for Surface Water, the proposed Newton-in-Bowland TBM Drive site compound area and the temporary access roads are at low risk of surface water flooding. Due to an increase in impermeable surfaces, the proposed construction sites have the potential to increase surface water runoff during an extreme rainfall event, and therefore increasing the risk of flooding downstream. Surface water runoff from the proposed compound and the tracks adjacent to the compound would however be routed into a storage lagoon prior to discharge into the existing well head drain at greenfield runoff rates. The attenuation of runoff prior to discharge would ensure that there would be a negligible change to surface water runoff rates and that the impact to surface water flooding would be **negligible**. Whilst the surface water drainage strategy for the section of access road across the River Hodder floodplain has not yet been finalised, it is assumed that embedded mitigation would be implemented including the use of roadside	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			Existing land use is generally agricultural with an unclassified road between Newton-in-Bowland and Dunsop Bridge runs between the TBM Portal compound and the logistics compound and crosses the watercourse.		drainage to attenuate any increase in runoff rate and that the impact on surface water flood risk would be **negligible.**		
Reservoir Flood risk from Stocks Reservoir		Proposed access road and temporary bridge across the River Hodder.	**Low** EA reservoir flood mapping indicated that the failure of Stocks Reservoir would pose a risk to the access road and the temporary bridge across the River Hodder with maximum flood depths of more than 2 m and maximum flow velocities of more than 2 m/s. However, the likelihood of a reservoir flood during the construction phase of the Proposed Scheme is very low. Land uses include a Wastewater Treatment Works (WwTW) located on the right (north) bank and the B6478, which crosses the River Hodder approximately 200 m north of the proposed bridge.		The Proposed Scheme is remote from any of the reservoirs and does not include any works that would affect the probability of flooding from these reservoirs. Therefore, no potential effects on reservoir safety have been identified in this area and the magnitude of effects would be **negligible**. The proposed Bridge crossing would be a barrier to flood flows through the floodplain. Following the unlikely failure of the reservoir, the new bridge crossing would result in an increase in flood depths upstream of the structure. However, flood extents are not likely to increase due to the local topography, which rises relatively steeply away from the floodplain. With existing flood depths of more than 2 m predicted in the unlikely event of a reservoir failure, the impact is likely to result in small increases in flood depth and the overall flood risk impact is likely to be **negligible.**		Neutral

3. Groundwater flood risk - Enabling and Construction Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Secondary Undifferentiated Superficial Aquifer (Glacial Till)		Lower Houses Shaft	**Medium** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is medium.		Given the proposed depths of the shaft excavation to 10.5 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding within the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 7.7 m. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Lower Houses Attenuation Pond	**High** For the majority of the site, there is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). An exception lies in the northwest of the excavation where susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity).		Given the proposed depths of the excavation to 2 mbgl and groundwater levels at this location, no significant amount of groundwater would be expected to drain into the open excavation during construction. If dewatering were required, it would have a marginal beneficial effect on groundwater flood risk. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		Lower Houses Access Track	**Medium** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception lies in the northeast of the access track where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity) and joins with an unclassified road to the southwest (medium sensitivity) The most conservative sensitivity for this element is medium.		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Lower Houses Permanent Access Track	**High** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity),		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			productive land agriculture (e.g. wheat) (medium sensitivity), one access chamber associated with the existing aqueduct (less vulnerable, high sensitivity) and bounds an existing access track to the northeast (medium sensitivity). The most conservative sensitivity for this element is high.				
		Lower Houses Single-line Connection - open cut section connecting the existing pipeline to the tunnel	**Medium** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is medium.		Given the proposed depths of the excavation to 5 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 2.2 m. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Lower Houses Compound	**High** For the majority of the site, there is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Exceptions exist in the west of the		No changes to groundwater levels would be anticipated as no dewatering would be required for construction of the compound. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			compound where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity) and for small areas in the north and east of the compound where the susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), one access chamber associated with the existing aqueduct (less vulnerable, high sensitivity) and is bounded by an unclassified road to the southwest (medium sensitivity). The most conservative sensitivity for this element is high.				
		Newton-in-Bowland Compound Portal	**Low** For the majority of the site, no significant risk of groundwater emergence has been identified			Given the proposed maximum depth of the portal excavation to 11 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding within the	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			by the BGS (2020) (low sensitivity). An exception lies in the north of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) The most conservative sensitivity for this element is low.			excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 8.2 m. The magnitude of change to groundwater flood risk would therefore be a **minor beneficial** change.	
		Newton-in-Bowland Attenuation Pond	**Medium**	For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the east of the excavation where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), bounded by an existing access track (medium sensitivity) and an		Given the proposed depths of the excavation to 2 mbgl and anticipated groundwater levels at this location, no significant amount of groundwater would be expected to drain into the open excavation during construction. If dewatering were required, it would have a marginal beneficial effect on groundwater flood risk. The magnitude of change to groundwater flood risk would therefore be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			unclassified road to the north (medium sensitivity). Most conservative land use sensitivity is medium.				
		Access track within Newton-in-Bowland Compound	**High** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the northwest of the construction footprint where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), bounded by an access chamber associated with the existing aqueduct (less vulnerable, high sensitivity) and joins the B6478 highway (high sensitivity) to the south.		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			The most conservative sensitivity for this element is high.				
		Construction Access route to/from Newton-in-Bowland Compound	**Very High** The potential risk of groundwater emergence is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity) and Very High (potential for groundwater flooding to occur at surface level) (BGS, 2020) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), the site lies adjacent to the B6478 to the east and north (high sensitivity) and a sewage treatment plant (essential infrastructure, very high sensitivity). The most conservative sensitivity for this element is very high.		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Newton-in-Bowland Multi-line Connection - open cut section connecting the	**Low** For the majority of the site, no risk of groundwater emergence has been identified by the BGS (2020). In the southeast of the excavation the susceptibility of		Given the proposed depths of the excavation to 3 mbgl, a small emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 0.2 m.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		existing pipeline to the tunnel	groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.		Any dewatering would have a betterment effect on fluvial flood risk due to a reduction of baseflow, although the size of the impact would depend on the abstraction rate and amount of baseflow which is unknown. As such, the impacts to both Unnamed Watercourse 384 and Unnamed Watercourse 385 due southwest have not been assessed as no increase to the contribution to baseflow would be expected. The magnitude of change to groundwater flood risk would therefore be **negligible**.		
		Newton-in-Bowland Single-line Overflow - open-cut excavation required to allow a pipe to be laid for discharge from the proposed tunnel to surface water drainage.	**Low** For the majority of the site, no significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the southeast of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.		Given the proposed depths of the excavation to 3 mbgl, a small emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 0.2 m. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Newton-in-Bowland Compound	**High** For the majority of the site, there is a Very Low to Low potential		No changes to groundwater levels would be anticipated as no dewatering would be required for construction of the compound.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Exceptions exists in the south and west categorised as Moderate to Very High risk (potential for groundwater flooding to occur at surface level) (high sensitivity) (no risk of groundwater emergence has been identified by the BGS (2020) at the centre of the compound). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), the site is bounded by the B6478 highway (high sensitivity), two buildings used for agriculture (less vulnerable, high sensitivity). The most conservative sensitivity for this element is high.		The magnitude of change to groundwater flood risk would therefore be **negligible**.		
Secondary A Superficial Aquifer (River Terrace		Construction Access route to/from Newton-in-Bowland Compound	**Very High** The potential risk of groundwater emergence is classified as Moderate to High (potential for		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Deposits and Alluvium)			flooding of below ground properties) (medium sensitivity) and Very High (potential for groundwater flooding to occur at surface level) (BGS, 2020) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), the site lies adjacent to the B6478 to the east and north (high sensitivity) and a sewage treatment plant (essential infrastructure, very high sensitivity). The most conservative sensitivity for this element is very high.				
No superficial deposits are identified on BGS mapping (BGS, 2020)		Lower Houses Multi-line Connection - open cut section connecting the existing pipeline to the tunnel	**High** For the majority of the site, no risk of groundwater emergence has been identified by the BGS (2020). In the north of the excavation the susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity),		Given the proposed depths of the excavation to 5 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 2.2 m. Any dewatering would have a betterment effect on fluvial flood risk due to a reduction of baseflow, although the size of the impact would depend on the abstraction rate and amount of baseflow which is unknown. As such, the magnitude of impact to Cod Gill due northwest has not been assessed although any impacts in terms of groundwater flood risk would be		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity) and one access chamber associated with the existing aqueduct (less vulnerable, high sensitivity). The most conservative sensitivity for this element is high.		beneficial as no increase to the contribution to baseflow would be expected. The magnitude of change to groundwater flood risk would therefore be **negligible**.		
Secondary A Bedrock Aquifer (Millstone Grit Group)		Lower Houses Shaft	**Medium** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is medium.		Given the proposed depths of the shaft excavation to 10.5 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding within the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 7.7 m. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Lower Houses Attenuation Pond	**High** For the majority of the site, there is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). An exception lies in the northwest of the excavation where		Given the proposed depths of the excavation to 2 mbgl and groundwater levels at this location, no significant amount of groundwater would be expected to drain into the open excavation during construction. If dewatering were required, it would have a marginal beneficial effect on groundwater flood risk. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity).				
		Lower Houses Access Track	**Medium** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception lies in the northeast of the access track where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity) and joins with an unclassified road to the southwest (medium sensitivity) The most conservative sensitivity for this element is medium.		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		Lower Houses Permanent Access Track	**High** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), one access chamber associated with the existing aqueduct (less vulnerable, high sensitivity) and bounds an existing access track to the northeast (medium sensitivity). The most conservative sensitivity for this element is high.		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Lower Houses Multi-line Connection - open cut section connecting the existing pipeline to the tunnel	**High** For the majority of the site, no risk of groundwater emergence has been identified by the BGS (2020). In the north of the excavation the susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity).		Given the proposed depths of the excavation to 5 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 2.2 m. Any dewatering would have a betterment effect on fluvial flood risk due to a reduction of baseflow, although the size of the impact would depend on the abstraction rate and amount of baseflow which is unknown. As such, the magnitude of impact to Cod Gill due northwest has not been assessed although any impacts in terms of groundwater flood risk would be		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity) and one access chamber associated with the existing aqueduct (less vulnerable, high sensitivity). The most conservative sensitivity for this element is high.		beneficial as no increase to the contribution to baseflow would be expected. The magnitude of change to groundwater flood risk would therefore be **negligible**.		
		Lower Houses Single-line Connection - open cut section connecting the existing pipeline to the tunnel	**Medium** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is medium.		Given the proposed depths of the excavation to 5 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 2.2 m. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Lower Houses Compound	**High** For the majority of the site, there is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Exceptions		No changes to groundwater levels would be anticipated as no dewatering would be required for construction of the compound. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
				exist in the west of the compound where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity) and for small areas in the north and east of the compound where the susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), one access chamber associated with the existing aqueduct (less vulnerable, high sensitivity) and is bounded by an unclassified road to the southwest (medium sensitivity). The most conservative sensitivity for this element is high.			
Secondary A Bedrock Aquifer (Hodder Mudstone Formation)		Newton-in-Bowland Compound Portal	**Low** For the majority of the site, no significant risk of groundwater		Given the proposed maximum depth of the portal excavation to 11 mbgl, an emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding within the		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the north of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) The most conservative sensitivity for this element is low.		excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 8.2 m. The magnitude of change to groundwater flood risk would therefore be a **minor beneficial** change.		
		Newton-in-Bowland Attenuation Pond	**Medium** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the east of the excavation where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), bounded by an existing access		Given the proposed depths of the excavation to 2 mbgl and anticipated groundwater levels at this location, no significant amount of groundwater would be expected to drain into the open excavation during construction. If dewatering were required, it would have a marginal beneficial effect on groundwater flood risk. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			track (medium sensitivity) and an unclassified road to the north (medium sensitivity). Most conservative land use sensitivity is medium.				
		Access track within Newton-in-Bowland Compound	**High** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the northwest of the construction footprint where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), bounded by an access chamber associated with the existing aqueduct (less vulnerable, high sensitivity) and joins the B6478 highway (high sensitivity) to the south.			No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			The most conservative sensitivity for this element is high.				
		Construction Access route to/from Newton-in-Bowland Compound	**Very High** The potential risk of groundwater emergence is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity) and Very High (potential for groundwater flooding to occur at surface level) (BGS, 2020) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), the site lies adjacent to the B6478 to the east and north (high sensitivity) and a sewage treatment plant (essential infrastructure, very high sensitivity). The most conservative sensitivity for this element is very high.		No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Newton-in-Bowland Multi-line Connection - open cut section connecting the	**Low** For the majority of the site, no risk of groundwater emergence has been identified by the BGS (2020). In the southeast of the excavation the susceptibility of		Given the proposed depths of the excavation to 3 mbgl, a small emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 0.2 m.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		existing pipeline to the tunnel	groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.		Any dewatering would have a betterment effect on fluvial flood risk due to a reduction of baseflow, although the size of the impact would depend on the abstraction rate and amount of baseflow which is unknown. As such, the impacts to both Unnamed Watercourse 384 and Unnamed Watercourse 385 due southwest have not been assessed as no increase to the contribution to baseflow would be expected. The magnitude of change to groundwater flood risk would therefore be **negligible**.		
		Newton-in-Bowland Single-line Overflow - open-cut excavation required to allow a pipe to be laid for discharge from the proposed tunnel to surface water drainage.	**Low** For the majority of the site, no significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the southeast of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.		Given the proposed depths of the excavation to 3 mbgl, a small emergence of groundwater would be expected inside the open excavation during construction. Appropriate drainage strategies embedded into the design would be implemented to mitigate for flooding in the excavation. Groundwater drawdown would occur down to the base of the excavation, lowering the water table potentially by 0.2 m. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Newton-in-Bowland Compound	**High** For the majority of the site, there is a Very Low to Low potential		No changes to groundwater levels would be anticipated as no dewatering would be required for construction of the compound.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Exceptions exists in the south and west categorised as Moderate to Very High risk (potential for groundwater flooding to occur at surface level) (high sensitivity) (no risk of groundwater emergence has been identified by the BGS (2020) at the centre of the compound). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), the site is bounded by the B6478 highway (high sensitivity), two buildings used for agriculture (less vulnerable, high sensitivity). The most conservative sensitivity for this element is high.		The magnitude of change to groundwater flood risk would therefore be **negligible**.		
Secondary A Bedrock Aquifer (Chatburn Limestone Formation)		Newton-in-Bowland Compound	**High** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence		No changes to groundwater levels would be anticipated as no dewatering would be required for construction of the compound. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
				(limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Exceptions exists in the south and west categorised as Moderate to Very High risk (potential for groundwater flooding to occur at surface level) (high sensitivity) (no risk of groundwater emergence has been identified by the BGS (2020) at the centre of the compound). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), the site is bounded by the B6478 highway (high sensitivity), two buildings used for agriculture (less vulnerable, high sensitivity). The most conservative sensitivity for this element is high.			

4. Fluvial flood risk – Commissioning Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Cod Gill	Ordinary Watercourse	The exact location of the attenuation lagoons and dechlorination plant required for commissioning has not been finalised, but they would be located within the planning application boundary around the Lower Houses Construction Compound approximately 50 m East of Cod Gill. An outfall pipe would discharge to this watercourse.	**High**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. The surrounding land is agricultural. Lower House Farm is adjacent to Cod Gill downstream of the Proposed Scheme but is outside of its predicted flood extents.		The proposed commissioning phase infrastructure would be at low risk of fluvial flooding from this watercourse. Therefore, the main potential impact would be from the discharge of water used to flush debris from the new aqueduct. This discharge would have the potential to result in an increase fluvial flow rates within the watercourse and increase flood risk downstream. All discharges would be subject to environmental permits. The discharge rates would be attenuated to a maximum of 25 l/s or 10 ML per day, with continuous discharge lasting for approximately four to six weeks. Data on dry weather and flood flow rates within the receiving watercourses and the capacity of any key pinch points such as culvert crossings were not made available at the time of writing this FRA. Although the discharge would be attenuated and very short in duration, it is not possible to assess the actual impact that these discharges would have on flood risk downstream. It is therefore assumed that the impact would be **moderate** and that additional mitigation would be required, which discussed in the FRA report.	Moderate/ Large
River Hodder	Main River	Newton-in-Bowland TBM Drive Site Compound and temporary lagoons with the associated dechlorinating plants and connecting pipework. The exact location of the attenuation	**High**	Flood Zone 3 Flood Zone mapping and an analysis of the existing topography indicates that the floodplain in this area would be confined within a floodplain approximately		The proposed commissioning phase infrastructure would be at low risk of fluvial flooding from this watercourse. Therefore, the main potential impact would be from the discharge of water used to flush debris from the new aqueduct. This discharge would have the potential to result in an increase fluvial flow rates within the watercourse and increase flood risk downstream. All discharges would be subject to environmental permits. The discharge rates would be attenuated to a maximum of 25 l/s or 10 ML per day, with continuous discharge lasting for approximately four to six weeks.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		lagoons and dechlorination plant required for commissioning has not been finalised, but they would be located within the planning application boundary around the Newton-in-Bowland Construction Compound approximately 200 m north of the River Hodder.	200 m wide by high ground to the north and south. Existing land use includes agricultural land and a waste water treatment works (WwTW) located on the right (north) bank and the B6478 which crosses the River Hodder approximately 200 m north of the proposed bridge location via an existing masonry bridge which has a double arch and a pier within the channel of the River Hodder.		A comparison of anticipated commissioning flows with estimated QMED flood flows within the River Hodder has been undertaken. This indicates that the discharge from the commissioning activities would be less than 1% of the QMED flow within River Hodder. Therefore, it is considered that the impact on flood risk along the River Hodder to downstream receptors would be **negligible**.		

5. Groundwater flood risk – Commissioning Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
					No impacts identified		

6. Other sources of flood risk – Commissioning Phase Marl Hill Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Surface water flooding in the vicinity of the Lower Houses TBM Reception site compound		Lower Houses TBM Reception site compound and the temporary access road. Temporary lagoons with the associated dechlorinating plants and connecting pipework.	**Low**	The Flood Map for Surface Water indicates that the general probability of surface water flooding across the catchment is low (less than 0.1% AEP). However, areas of higher risk do exist, but these are associated with watercourses and are assessed under the fluvial flood risk section.		Assuming that the commissioning phase infrastructure would be located away from any localised areas of high surface water risk, the risk to commissioning activities from surface water would be low. The attenuation lagoons would however be new open raised structures and would be a new source of potential flooding in the event that they overtop or fail. It is assumed that as new open structures, they would collect direct rainfall. It is expected that this would be taken into account during the detail design of the structure and either additional capacity (freeboard) is provided or a process developed to make available the necessary capacity once the flushing process begins. With this additional freeboard and management, the risk of overtopping is low. Since, these would also be new structures, the risk of failure would also be low. Large lagoons would also have the potential to divert surface water flowpaths. However, the lagoons would be located within areas with a low risk of surface water flooding and therefore, the impact on the diversion of flows would be **negligible**.	Neutral
Surface water flooding in the vicinity of the Newton-in-Bowland TBM Drive site compound		Newton-in-Bowland TBM Drive site compound and temporary access road. Temporary lagoons with the associated dechlorinating plants and connecting pipework.	**Low**	The Flood Map for Surface Water indicates that the general the probability of surface water flooding across the catchment is low (less than 0.1% AEP). However, there are localised areas along the existing access track and on the Newton to Dunsop Bridge road which would flood up to a maximum		Assuming that the commissioning phase infrastructure would be located away from the localised areas of high surface water risk, the risk to commissioning activities from surface water would be low. The attenuation lagoons would however be new open raised structures and would be a new source of potential flooding in the event that they overtop or fail. It is assumed that as new open structures, they would collect direct rainfall. It is expected that this would be taken into account during the detail design of the structure and either additional capacity (freeboard) is provided or a process developed to make available the necessary capacity once the flushing process begins. With this additional freeboard and management, the risk of overtopping is low. Since, these would also be new structures, the risk of failure would also be low.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
				depth of 300 mm during a 1% AEP rainfall event. Existing land use is generally agricultural with an unclassified road between Newton-in-Bowland and Dunsop Bridge runs between the TBM Portal compound and the logistics compound and crosses the watercourse.		Large lagoons would also have the potential to divert surface water flowpaths. However, the lagoons would be located within areas with a low risk of surface water flooding and therefore, the impact on the diversion of flows would be **negligible**.	

7. Fluvial flood risk – Operational Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Cod Gill (Ordinary Watercourse)		A new Valve house is proposed approximately 30 m south (upgradient) of the watercourse. The existing permanent access track would be extended to enable access to this building.	**High**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. The surrounding land is agricultural. Lower House Farm is adjacent to Cod Gill Downstream of the Proposed Scheme but is outside of its predicted flood extents.		The proposed new permanent valve house building and its associated permanent access track at the Lower Houses TBM Reception site compound would be at low risk of fluvial flooding. It is assumed that all surface water runoff from the new permanent valve house building would be captured and attenuated using sustainable drainage techniques and either discharge to the watercourse at greenfield runoff rates or discharged to the ground. Therefore, the impact on fluvial flood risk downstream would be **negligible**.	Neutral
Unnamed Watercourse 385 and 384 Ordinary Watercourse (Tributary of the Main River Hodder)		A new Valve house is proposed approximately 30 m south (upgradient) of the watercourse. The existing permanent access track would be extended to enable access to this building.	**High**	Flood Zone 1 Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding from this watercourse is greater than or equal to 3.33% AEP. The surrounding land is agricultural and an existing unclassified road between Newton-in-Bowland and		The proposed new permanent valve house building and its associated access track at the Newton-in-Bowland TBM Drive site compound would be at low risk of fluvial flooding. It is assumed that all surface water runoff from the new permanent valve house building would be captured and attenuated using sustainable drainage techniques and either discharge to the watercourse at greenfield runoff rates or discharged to the ground. Therefore, the impact on fluvial flood risk downstream would be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
				Dunsop Bridge runs between the TBM Portal compound and the logistics compound and crosses the watercourse.			

8. Groundwater flood risk - Operational Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Secondary Undifferentiated Superficial Aquifer (Glacial Till)		Lower Houses Shaft	**Medium**	There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is medium.		The proposed shaft, 15 m in diameter and 10.5 m deep, could act as a very localised barrier to groundwater flow potentially leading to a localised rise of the water table up hydraulic gradient of the structure. The magnitude of change to groundwater flood risk would therefore be **negligible**.	Neutral
		Reinstated Lower Houses Attenuation Pond	**High**	For the majority of the site, there is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). An		The attenuation pond is assumed to be reinstated to ground level. The associated backfilling of the excavation could lead to permanent localised alterations in groundwater flows and levels at the site, depending on the use of arisings / granular bedding material. However, due to the relatively shallow depth of the excavation it is not considered deep enough to significantly affect groundwater flow.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			exception lies in the northwest of the excavation where susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is high.		The magnitude of change to groundwater flood risk would therefore be **negligible**.		
		Lower Houses Permanent Access Track	**High** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), a redundant aqueduct building/ infrastructure (access chamber) (low sensitivity), newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity) and bounds an existing access track		No significant change to groundwater levels would be expected in the long term as works are not expected to reach the water table. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source Name	Flood Source Type	Proposed Scheme Element	Likelihood / Importance Score	Likelihood / Importance Justification	Magnitude of Change Score	Magnitude of Change Justification	Significance Score
			to the northeast (medium sensitivity). The most conservative sensitivity for this element is high.				
		Lower Houses Single-line Connection - open cut section connecting the existing pipeline to the Proposed Bowland Tunnel	**High** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity) and newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.			The open-cut construction method proposed for the Lower Houses Connection excavations, means that the trench would need to be backfilled with arisings or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.	Neutral
		Newton-in-Bowland Compound Portal	**Low** For the majority of the site, no significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the north of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for			The proposed portal excavation, approximately 70 m by 45 m in length and width respectively and 11 m deep, could act as a localised barrier to groundwater flow potentially leading to a localised rise of the water table up hydraulic gradient of the structure. The magnitude of change to groundwater flood risk would therefore be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) The most conservative sensitivity for this element is low.				
		Access track within Newton-in-Bowland Compound	**High** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the northwest of the construction footprint where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), bounded by a redundant aqueduct building/ infrastructure (access chamber) (low sensitivity), joins the B6478 highway (high sensitivity) to the		No significant change to groundwater levels would be expected in the long term as works are not expected to reach the water table. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			south and lies adjacent to the newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.				
		Newton-in-Bowland Multi-line Connection - open cut section connecting the existing pipeline to the Proposed Bowland Tunnel	**High** For the majority of the site, no significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the southeast of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) and newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.		The open-cut construction method proposed for the Newton-in-Bowland Connection, means that the trench would need to be backfilled with arisings or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Newton-in-Bowland Single-line Overflow - open-cut excavation required to allow a	**High** For the majority of the site, no significant risk of groundwater		The open-cut construction method proposed for the Newton-in-Bowland Overflow, means that the trench would need to be backfilled with arisings		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		pipe to be laid for discharge from the proposed tunnel to surface water drainage.		emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the southeast of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) and newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.		or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.	
		Reinstated Newton-in-Bowland Attenuation Pond	**Medium**	For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the east of the excavation where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of		The attenuation pond is assumed to be reinstated to ground level. The associated backfilling of the excavation could lead to permanent localised alterations in groundwater flows and levels at the site, depending on the use of arisings / granular bedding material. However, due to the relatively shallow depth of the excavation is not considered deep enough to significantly affect groundwater flow. The magnitude of change to groundwater flood risk would therefore be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), bounded by an existing access track (medium sensitivity) and an unclassified road to the north (medium sensitivity). Most conservative land use sensitivity is medium.				
No superficial deposits are identified on BGS mapping (BGS, 2020)		Lower Houses Multi-line Connection - open cut section connecting the existing pipeline to the Proposed Bowland Tunnel	**High** For the majority of the site, no risk of groundwater emergence has been identified by the BGS (2020). In the north of the excavation the susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), redundant aqueduct buildings/ infrastructure (access chamber) (low sensitivity) and newly constructed permanent		The open-cut construction method proposed for the Lower Houses Connection excavations, means that the trench would need to be backfilled with arisings or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.				
Secondary A Bedrock Aquifer (Millstone Grit Group)		Lower Houses Shaft	**Medium** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is medium.		The proposed shaft, 15 m in diameter and 10.5 m deep, could act as a very localised barrier to groundwater flow potentially leading to a localised rise of the water table up hydraulic gradient of the structure. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Reinstated Lower Houses Attenuation Pond	**High** For the majority of the site, there is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). An exception lies in the northwest of the excavation where susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity).		The attenuation pond is assumed to be reinstated to ground level. The associated backfilling of the excavation could lead to permanent localised alterations in groundwater flows and levels at the site, depending on the use of arisings / granular bedding material. However, due to the relatively shallow depth of the excavation it is not considered deep enough to significantly affect groundwater flow. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			Land use: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is high.				
		Lower Houses Permanent Access Track	**High** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), a redundant aqueduct building/ infrastructure (access chamber) (low sensitivity), newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity) and bounds an existing access track to the northeast (medium sensitivity). The most conservative sensitivity for this element is high.		No significant change to groundwater levels would be expected in the long term as works are not expected to reach the water table. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Lower Houses Multi-line Connection - open cut section connecting the	**High** For the majority of the site, no risk of groundwater emergence		The open-cut construction method proposed for the Lower Houses Connection excavations, means that the trench would need to be backfilled		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		existing pipeline to the Proposed Bowland Tunnel	has been identified by the BGS (2020). In the north of the excavation the susceptibility of groundwater flooding is classified as Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), redundant aqueduct buildings/ infrastructure (access chamber) (low sensitivity) and newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.		with arisings or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.	
		Lower Houses Single-line Connection - open cut section connecting the existing pipeline to the Proposed Bowland Tunnel	**High** There is a Moderate to High potential risk of groundwater emergence (potential for flooding of below ground properties) (BGS, 2020) (medium sensitivity). Land use: rough grazing farmland (low sensitivity) and newly constructed permanent		The open-cut construction method proposed for the Lower Houses Connection excavations, means that the trench would need to be backfilled with arisings or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.				
Secondary A Bedrock Aquifer (Hodder Mudstone Formation)		Newton-in-Bowland Compound Portal	**Low** For the majority of the site, no significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the north of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) The most conservative sensitivity for this element is low.		The proposed portal excavation, approximately 70 m by 45 m in length and width respectively and 11 m deep, could act as a localised barrier to groundwater flow potentially leading to a localised rise of the water table up hydraulic gradient of the structure. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral
		Access track within Newton-in-Bowland Compound	**High** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the northwest of the construction footprint		No significant change to groundwater levels would be expected in the long term as works are not expected to reach the water table. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), existing access track (medium sensitivity), bounded by a redundant aqueduct building/ infrastructure (access chamber) (low sensitivity), joins the B6478 highway (high sensitivity) to the south and lies adjacent to the newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.				
		Newton-in-Bowland Multi-line Connection - open cut section connecting the existing pipeline to the Proposed Bowland Tunnel	**High** For the majority of the site, no significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the southeast of the excavation where the susceptibility of groundwater flooding is classified			The open-cut construction method proposed for the Newton-in-Bowland Connection, means that the trench would need to be backfilled with arisings or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) and newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity). The most conservative sensitivity for this element is high.				
		Newton-in-Bowland Single-line Overflow - open-cut excavation required to allow a pipe to be laid for discharge from the proposed tunnel to surface water drainage.	**High** For the majority of the site, no significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). An exception lies in the southeast of the excavation where the susceptibility of groundwater flooding is classified as Very Low to Low (limited potential for groundwater flooding to occur) (low sensitivity). Land use: rough grazing farmland (low sensitivity) and newly constructed permanent building (New Well House) (Less Vulnerable, high sensitivity).		The open-cut construction method proposed for the Newton-in-Bowland Overflow, means that the trench would need to be backfilled with arisings or a granular bedding material. This could create a preferential groundwater flow path and a local groundwater drawdown. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			The most conservative sensitivity for this element is high.				
		Reinstated Newton-in-Bowland Attenuation Pond	**Medium** For the majority of the site, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). An exception exists in the east of the excavation where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). Land use: rough grazing farmland (low sensitivity), bounded by an existing access track (medium sensitivity) and an unclassified road to the north (medium sensitivity). Most conservative land use sensitivity is medium.		The attenuation pond is assumed to be reinstated to ground level. The associated backfilling of the excavation could lead to permanent localised alterations in groundwater flows and levels at the site, depending on the use of arisings / granular bedding material. However, due to the relatively shallow depth of the excavation is not considered deep enough to significantly affect groundwater flow. The magnitude of change to groundwater flood risk would therefore be **negligible**.		Neutral

9. Other sources of flood risk – Operational Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Surface water flooding in the vicinity of the Lower Houses Valve House		Valve house at Lower Houses TBM Reception site compound and the operational access road.	**Low** The Flood Map for Surface Water indicates that the general probability of surface water flooding across the catchment is low (less than 0.1% AEP). However, areas of higher risk have been identified, but these are associated with watercourses and are assessed under the fluvial flood risk section.		The proposed permanent valve house at Lower Houses is in this area has a low risk of surface water flooding. No designs are available for the proposed valve house. However, it is assumed that a drainage strategy would be developed during the detailed design stage to include sustainable drainage techniques to ensure runoff would be captured and attenuated and either discharge to the watercourse at greenfield runoff rates or discharged to the ground. Therefore, the impact on surface water flood risk would be **negligible**.		Neutral
Surface water flooding in the vicinity of the Newton-in-Bowland Valve House		Valve house at Newton-in-Bowland TBM Drive site compound and the operational access road.	**Low** The Flood Map for Surface Water indicates that whilst the probability of surface water flooding is generally low (less than 0.1% AEP). There are localised areas along the access track to the existing valve house and on the unclassified road which would flood up to a maximum depth of 300 mm during a 1% AEP surface water flood event. Existing land use is generally agricultural with an unclassified road passing through the area.		The operational infrastructure in this area has a low risk of surface water flooding. No designs are available for the proposed valve house. However, it is assumed that a drainage strategy would be developed during the detailed design stage to include sustainable drainage techniques to ensure that runoff would be captured and attenuated and either discharge to the watercourse at greenfield runoff rates or discharged to the ground. Therefore, the impact on surface water flood risk would be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Surface water flooding in the vicinity of Waddington Fell Quarry		Disposal of tunnel arisings within Waddington Fell Quarry.	**High**	The Flood Map for Surface Water indicates that the probability of surface water flooding is high with probability of flooding greater than or equal to 3.33% AEP. However, this mapping does not take into account the dewatering regime in place that would manage both surface and groundwater accumulating in the base of the quarry.		Disposal of material within the quarry would be undertaken in accordance with the licence conditions imposed on the quarry operator and any flood risk impacts would be the responsibility of the quarry operator to assess and manage.	
Reservoir Flood risk from Stocks Reservoir		None	**Low**	EA reservoir flood mapping indicated that the failure of Stocks Reservoir would pose a risk of flooding to receptors along the River Hodder floodplain including agricultural land, a Wastewater Treatment Works (WwTW) and the B6478. However, the likelihood of a reservoir flood during the construction phase of the Proposed Scheme is low.		The Proposed Scheme is remote from any of the reservoirs and does not include any works that would affect the probability of flooding from these reservoirs. Therefore, no potential effects on reservoir safety have been identified in this area and the magnitude of effects would be **negligible**.	Neutral

10. Fluvial flood risk – Decommissioning Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
River Hodder Main River		The existing overflow structure remains in situ and discharges to this river.	**High**	Flood Zone 3 Agricultural land is located downstream of the existing overflow.		The existing overflow structure remains in situ. However, the operation of the overflow would change as a result of the Proposed Scheme, which would now use the overflow to permanently discharge groundwater ingress from the existing section of aqueduct (to be decommissioned) into the River Hodder. The continuous discharge of groundwater has the potential to increase flood risk downstream of the discharge location. A comparison of anticipated groundwater discharge flows from the decommissioned section of aqueduct with estimated QMED flood flows within the River Hodder has been undertaken. This indicates that the discharge from the overflow would be less than 1% of the QMED flow within the beck. Therefore, it is considered that the impact on flood risk along the River Hodder to downstream receptors would be **negligible**.	Neutral

11. Groundwater flood risk - Decommissioning Phase Bowland Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Secondary Undifferentiated Superficial Aquifer (Glacial Till) Secondary Undifferentiated Bedrock Aquifer (Bowland Shale Formation)		Existing aqueduct running between Lower Houses and Newton-in-Bowland Compounds	**Very high**	For the majority of the length of the existing aqueduct, susceptibility for groundwater flooding at the existing aqueduct ranges from no significant risk to a Low risk (BGS, 2020) (low sensitivity). Small areas of High to Very		Once the new aqueduct is operational, the existing aqueduct will be decommissioned but remain in place. Ingress of groundwater into the existing aqueduct would be likely to occur over time representing a small dewatering rate (estimated at up to 139.5 l/s). This would be expected to generate a long-term groundwater drawdown over the length of the existing aqueduct at the Proposed Bowland Section. The magnitude of change to groundwater flood risk would therefore be a **minor beneficial** change.	Moderate (beneficial)

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Secondary A Bedrock Aquifers (Millstone Grit Group, Hodder Mudstone Formation, Chatburn Limestone Formation, Pendleside Limestone Formation and Hodderense Limestone Formation)				High potential risk generally lie in the north and south of the route (potential for groundwater flooding to occur at surface level) (high sensitivity). Land use: rough grazing farmland (low sensitivity), productive land agriculture (e.g. wheat) (medium sensitivity), unclassified roads (medium sensitivity), residential dwellings (More Vulnerable, very high sensitivity) and large areas of bracken, heath or rough grassland (Water Compatible Development, low sensitivity). The most conservative sensitivity for this element is very high.			

Annexe B: EIA Assessment Criteria

B.1 Baseline Sensitivity

192) The baseline sensitivity for flood sources considers the:

- Probability (likelihood) of flooding from the flood source considered e.g. Main Rivers, Ordinary Watercourses, groundwater etc. (the primary receptor) using probability values used by the Environment Agency on flood zone data
- Consequences of flooding as indicated by the vulnerability of receptors at risk (property, infrastructure, agricultural land etc.) using vulnerability classifications within the NPPF.

Table B-1: Baseline sensitivity criteria

Sensitivity Importance	Criteria
Low	▪ Fluvial – Land having a less than 0.1 % AEP of river flooding (Flood Zone 1) ▪ Surface water – Land having between 1 % and 0.1 % AEP of flooding from surface water ▪ Groundwater – Areas with limited potential for groundwater flooding to occur ▪ Artificial infrastructure – Areas at risk of flooding from failures of water infrastructure ▪ Land use that is defined within the NPPF as water-compatible.
Medium	▪ Fluvial – Land having between 1 % and 0.1 % AEP of river flooding (Flood Zone 2) ▪ Surface water – Land having between 1 % and 3.3 % AEP of flooding from surface water ▪ Groundwater – Areas with potential for groundwater flooding to receptors situated below ground level ▪ Land use including productive farmland or unclassified roads.
High	▪ Fluvial – Land having a greater than 1 % AEP of river flooding (Flood Zone 3) ▪ Surface water – Land having a greater than 3.3 % AEP of flooding from surface water ▪ Groundwater – Areas with potential for groundwater flooding to occur at surface level ▪ Land uses classified as less vulnerable within the NPPF, or local transport networks and infrastructure.
Very High	▪ Fluvial – Land where water has to flow or be stored in times of flood, referred to as Functional Floodplain (Flood Zone 3b) ▪ Land uses classified as essential infrastructure, more vulnerable, or highly vulnerable, or where the increase in flood risk would result in a risk to life (i.e. a flood hazard that is dangerous for all).

B.2 Magnitude of Change Criteria

193) The magnitude of change is a measure of the scale or extent of the change in the baseline condition, irrespective of the value of the resource(s) affected. However, flood risk can be influenced by several factors, including:

- Potential changes associated with the source of flooding linked to a change (or combination in changes) in runoff / higher discharge, flood storage volume, conveyance, flood frequency, depth / extent, velocity and / or peak flow
- Temporal changes to flooding such as permanent or temporary changes such as those that would be limited in duration to the construction period and those that would remain for the full duration of the operational life of the Proposed Bowland Section

- 'Embedded' mitigation measures that form part of an optimised design used to manage the likely significant flood risk effects.

194) The magnitude of change has been determined based on the factors listed above, the data available for flood sources and the criteria set within Table B-2. The term 'magnitude of effects' has been used to describe the severity of impacts within both the FRA and the Environmental Statement.

195) The overall baseline sensitivity was determined by the availability of data to determine probability for all flood sources and the potential for multiple receptors to be at risk. Where there was uncertainty regarding whether a receptor would be at risk, a precautionary approach was taken.

Table B-2: Magnitude of change criteria

Magnitude	Criteria
Major	A large adverse or beneficial change in flood depth, flood extent, velocity or peak flow that may have an impact some distance upstream or downstream. Potential to significantly change flood frequency. Potential change in risk to life. A large adverse or beneficial change in groundwater levels and flows that would affect groundwater flooding susceptibility over catchment scale.
Moderate	A moderate adverse or beneficial change in flood depth, flood extent or peak flow that may have limited impact some distance upstream or downstream. Potential for some change in flood frequency. Minor changes in floodplain flow pathways that increase velocity or extent of flooding but would not lead to new areas being inundated or new flow pathways forming. A moderate adverse or beneficial change in groundwater levels and flows that would affect groundwater flooding susceptibility over catchment scale, or a large adverse or beneficial change in groundwater levels and flows that would affect groundwater flooding susceptibility over local scale.
Minor	A small or very localised adverse or beneficial change in flood depth, extent or peak flow with no perceptible impact upstream or downstream or in the floodplain. Small changes in flood frequency. A small adverse or beneficial change in groundwater levels and flows that would affect groundwater flooding susceptibility over catchment scale, or a moderate adverse or beneficial change in groundwater levels and flows that would affect groundwater flooding susceptibility over local scale.
Negligible	Very limited potential for change. No change in flood frequency.

B.3 Significance of Impacts

196) The significance of the overall flood risk is a product of the likelihood (sensitivity / value) and the magnitude of the impacts. Should the overall significance of flood risk be classified as moderate, large or very large, additional mitigation would be required. Any effects that cannot be mitigated would be recorded as residual effects.

197) The overall risk of flooding during the construction and operational phases is a product of the likelihood of occurrence and the severity of impact as indicated in Table B-3.

Table B-3: Significance of flood risk Impacts

		Magnitude of Impact			
		Negligible	**Minor**	**Moderate**	**Major**
Baseline Flood Risk	**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

Annexe C: Figures

Figure 1 – Proposed Bowland Section Location and Layout

Figure 2 – The Flood Map for Planning

Figure 3 – The Risk of Flooding from Surface Water Map

Figure 4 – Areas Susceptible to Groundwater

Figure 5 – Risk of flooding from Reservoirs Map

Refer to Planning Application drawings for further details on drainage.

PROPOSED LOWER HOUSES COMPOUND PERMANENT SITE LAYOUT (Ref: 80061155-01-JAC-TR3-97-DR-C-00002)

PROPOSED NEWTON IN BOWLAND COMPOUND PERMANENT SITE LAYOUT (Ref: 80061155-01-JAC-TR3-97-DR-C-00004)

PROPOSED RIBBLE CROSSING BRIDGE GENERAL ARRANGEMENT AND ELEVATIONS (Ref: 80061155-01-JAC-TR3-97-DR-C-00009)

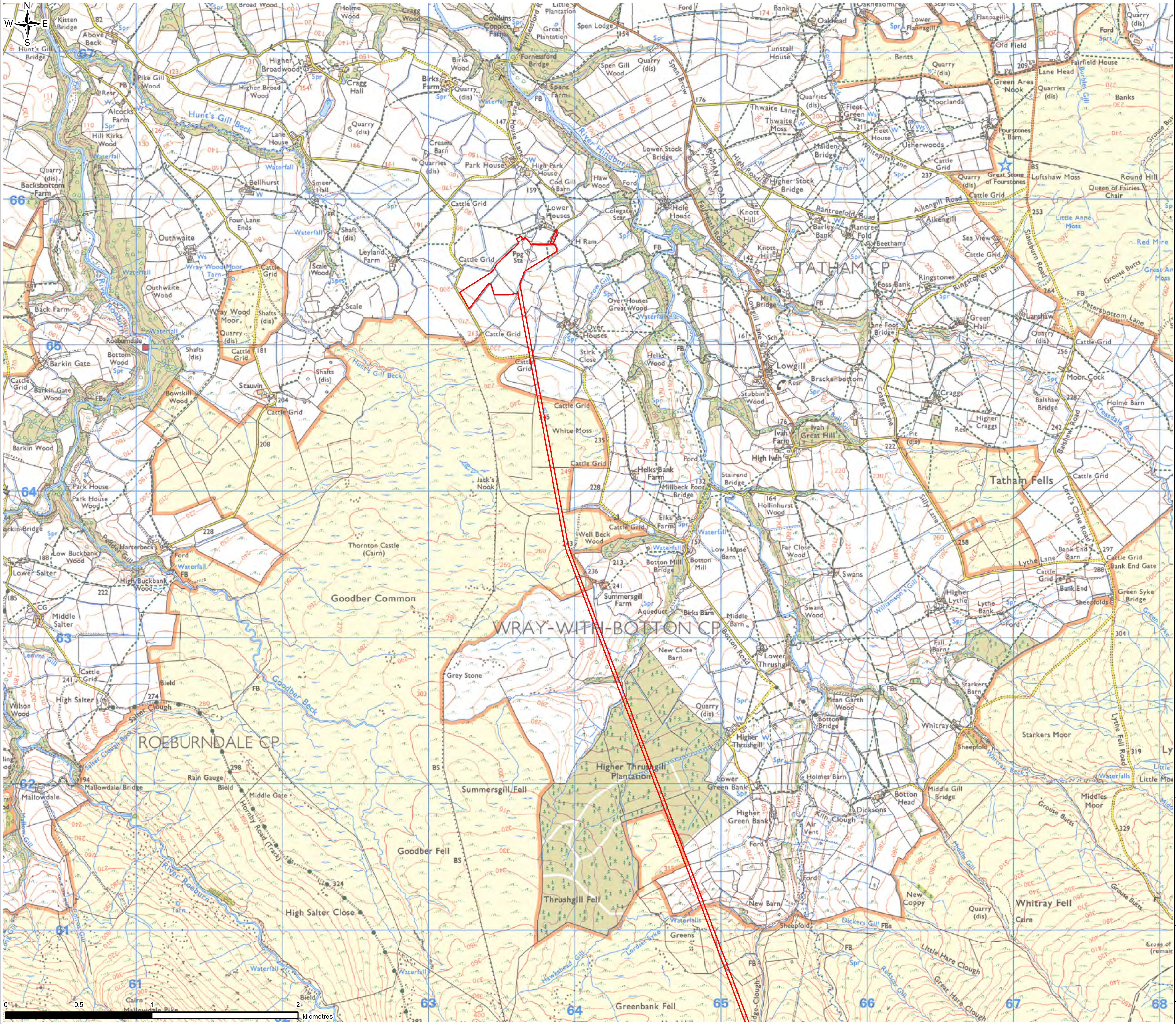
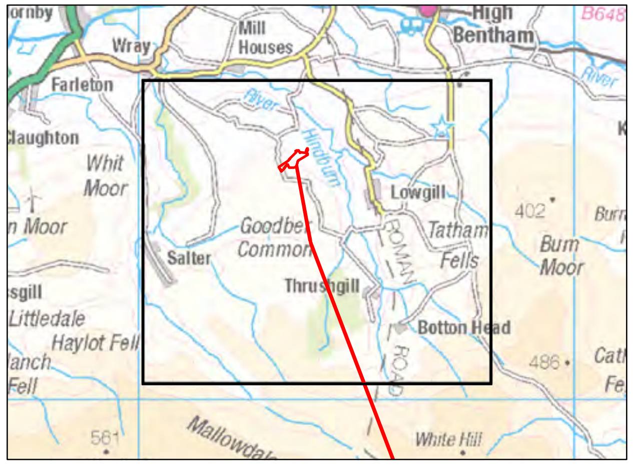


FIGURE 1

Legend

Planning Application Boundary



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SCHEME OVERVIEW
PAGE 1 OF 3

SCALE	SHEET SIZE
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DRAWING NUMBER	REVISION
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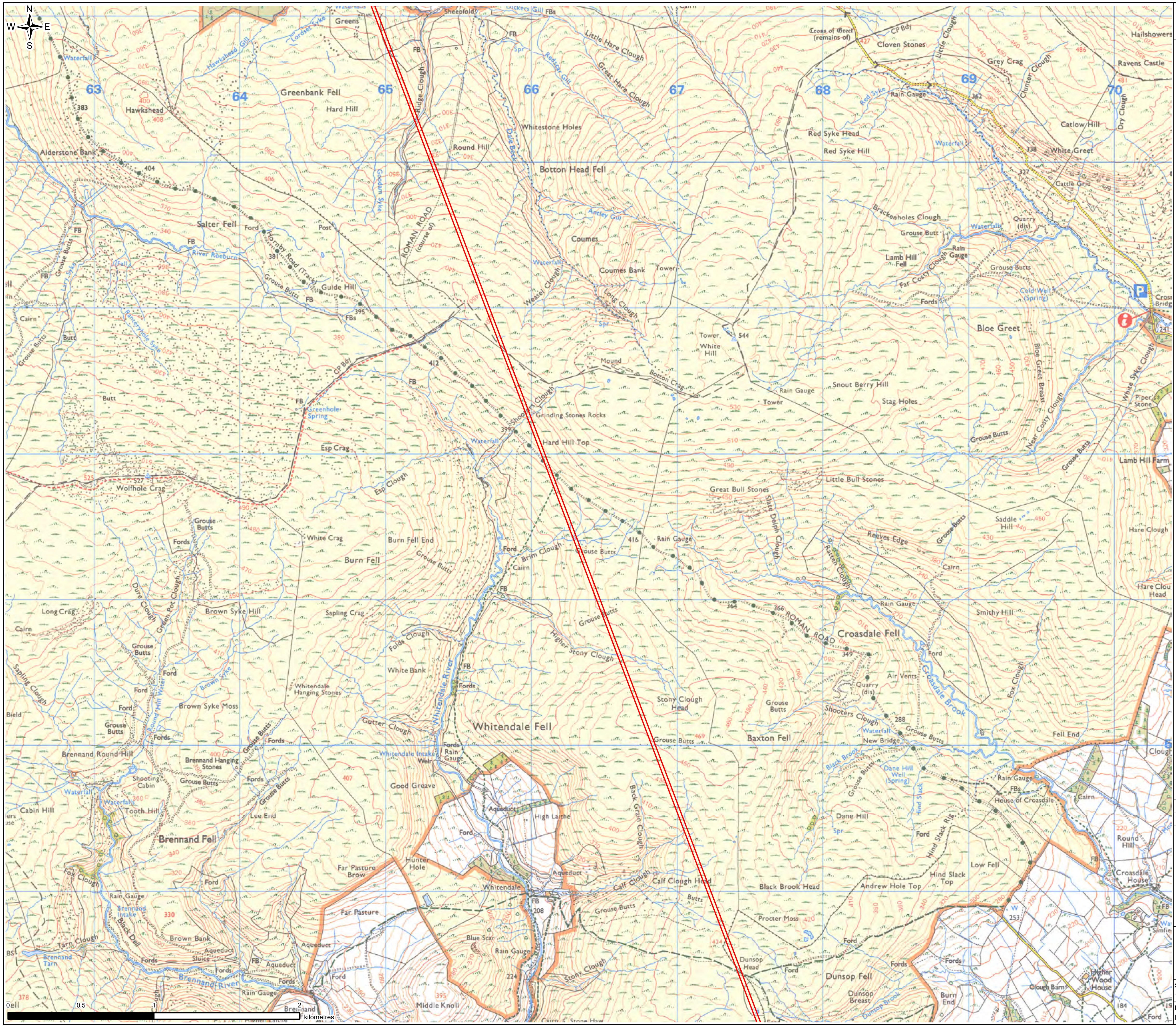
FIGURE 1



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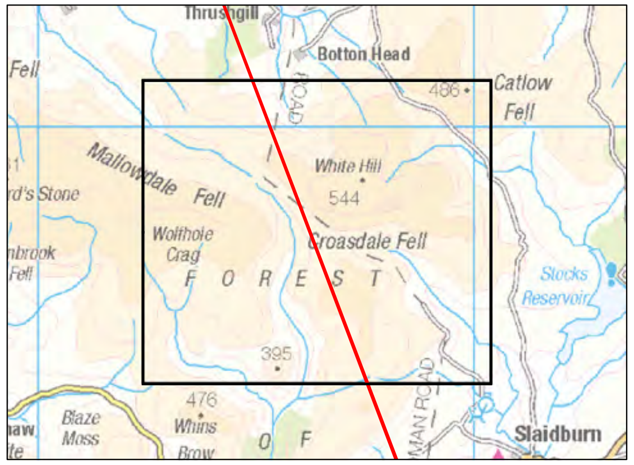

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SCHEME OVERVIEW
PAGE 2 OF 3

SCALE	SHEET SIZE
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DRAWING NUMBER	REVISION
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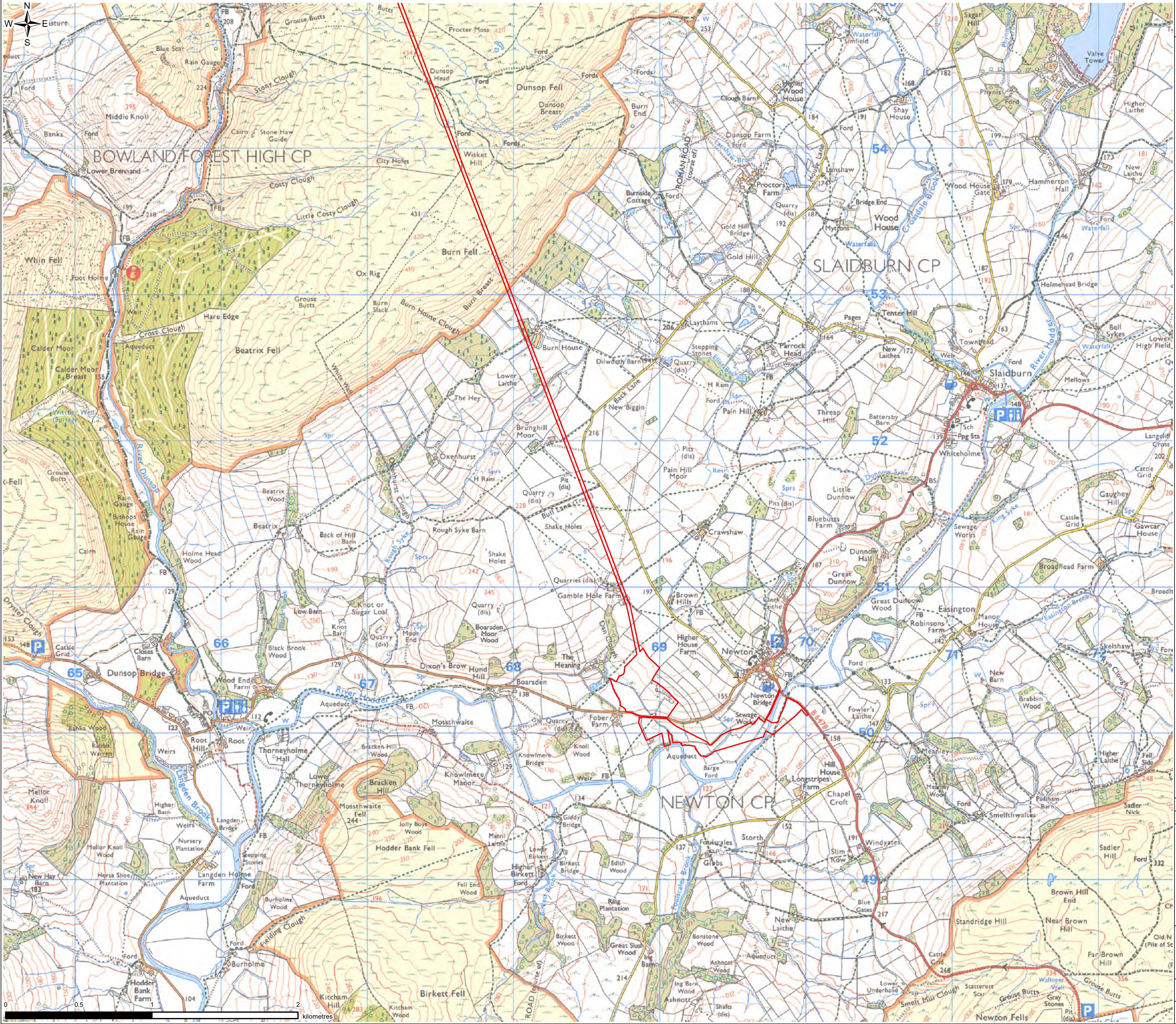

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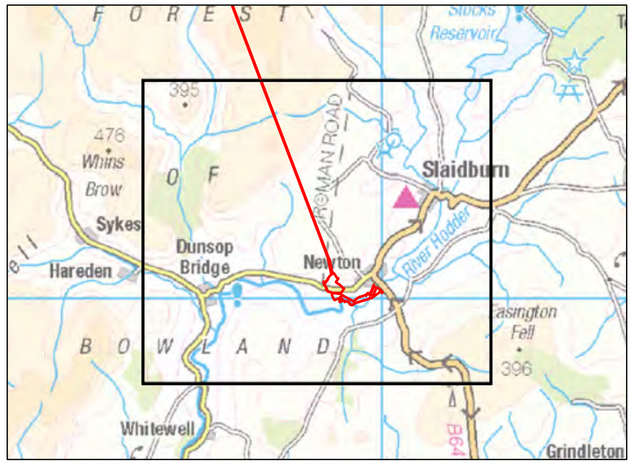

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SCHEME OVERVIEW
PAGE 3 OF 3

SCALE	SHEET SIZE
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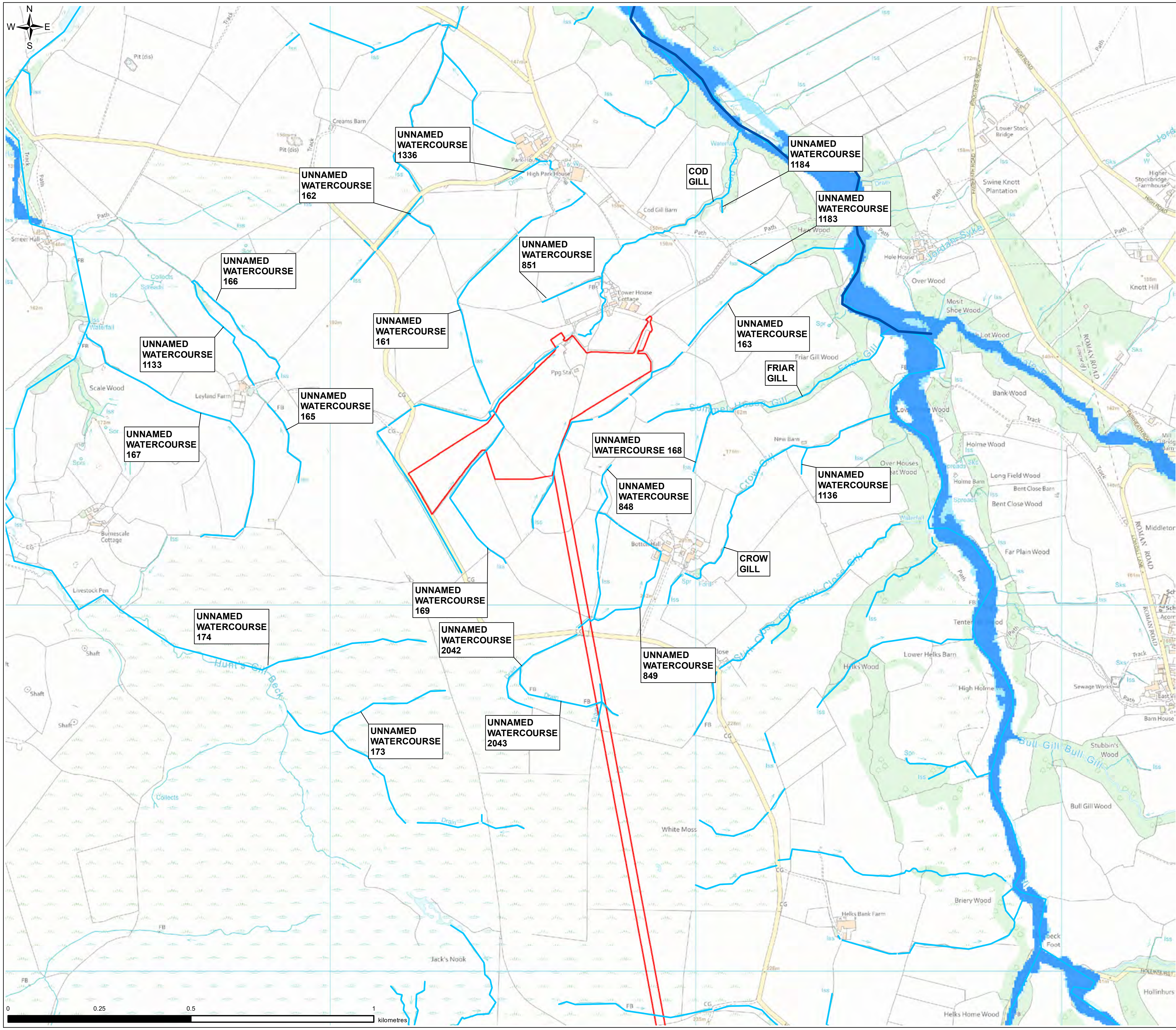
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-001	0

FIGURE 2



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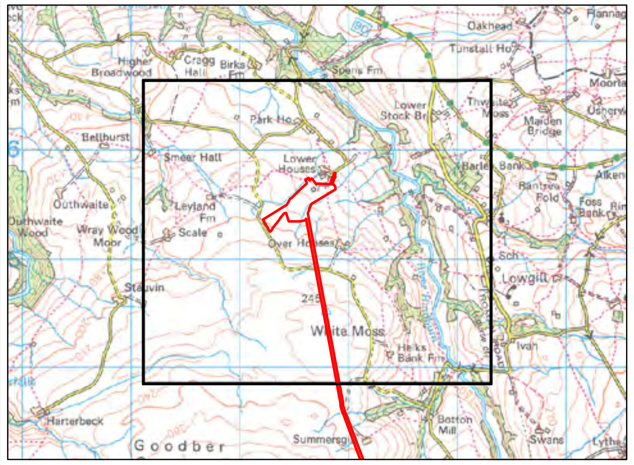
- Environment Agency Main Rivers
- Watercourses
- Flood Zone 3
- Flood Zone 2



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VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

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HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
FLUVIAL FLOOD RISK
PAGE 1 OF 7

SCALE	SHEET SIZE
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DRAWING NUMBER	REVISION
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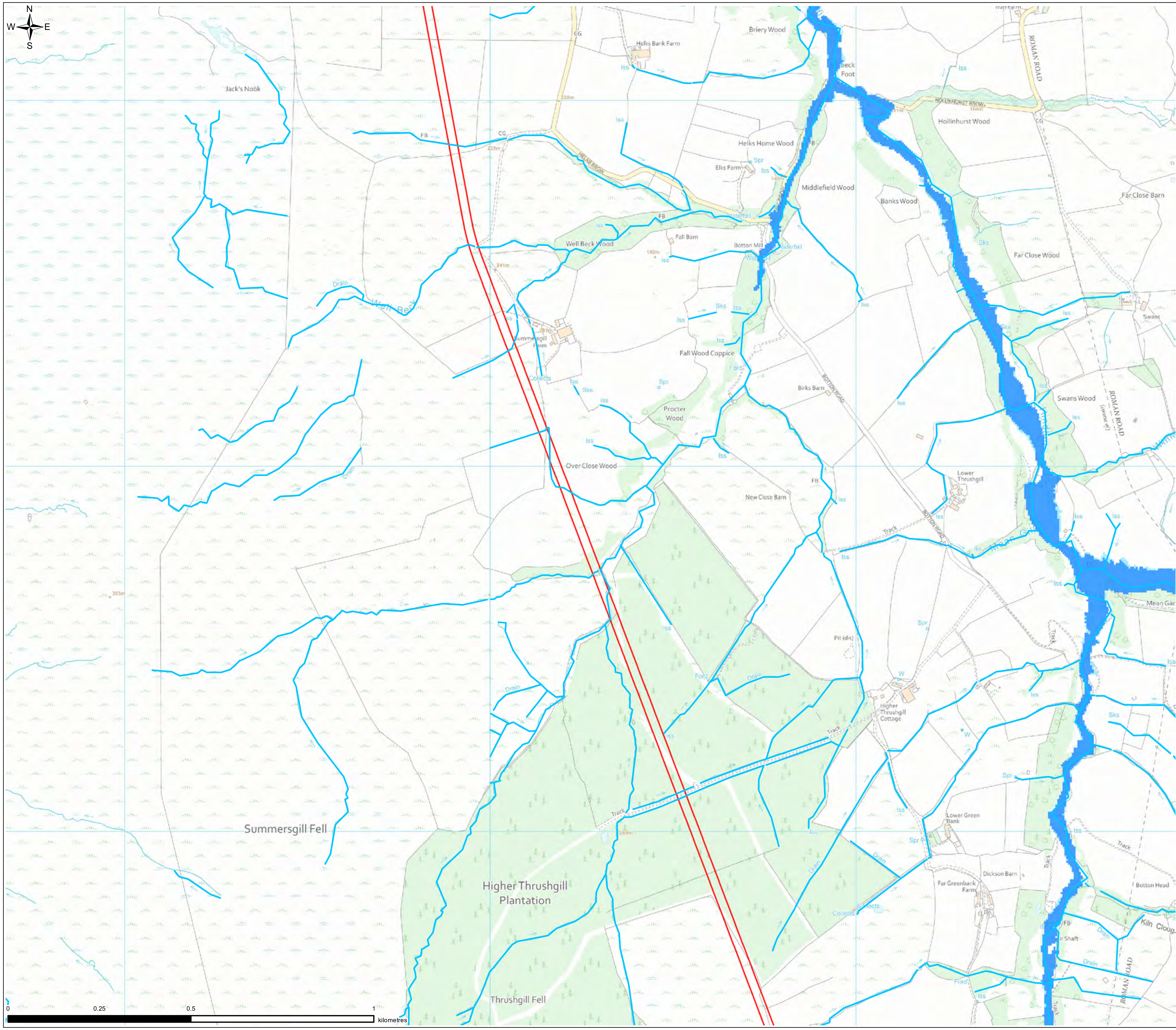
FIGURE 2



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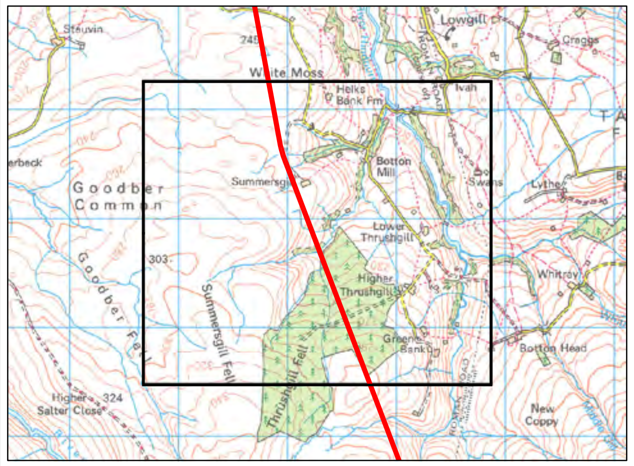
- Flood Zone 2



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HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
FLUVIAL FLOOD RISK
PAGE 2 OF 7

SCALE	SHEET SIZE
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DRAWING NUMBER	REVISION
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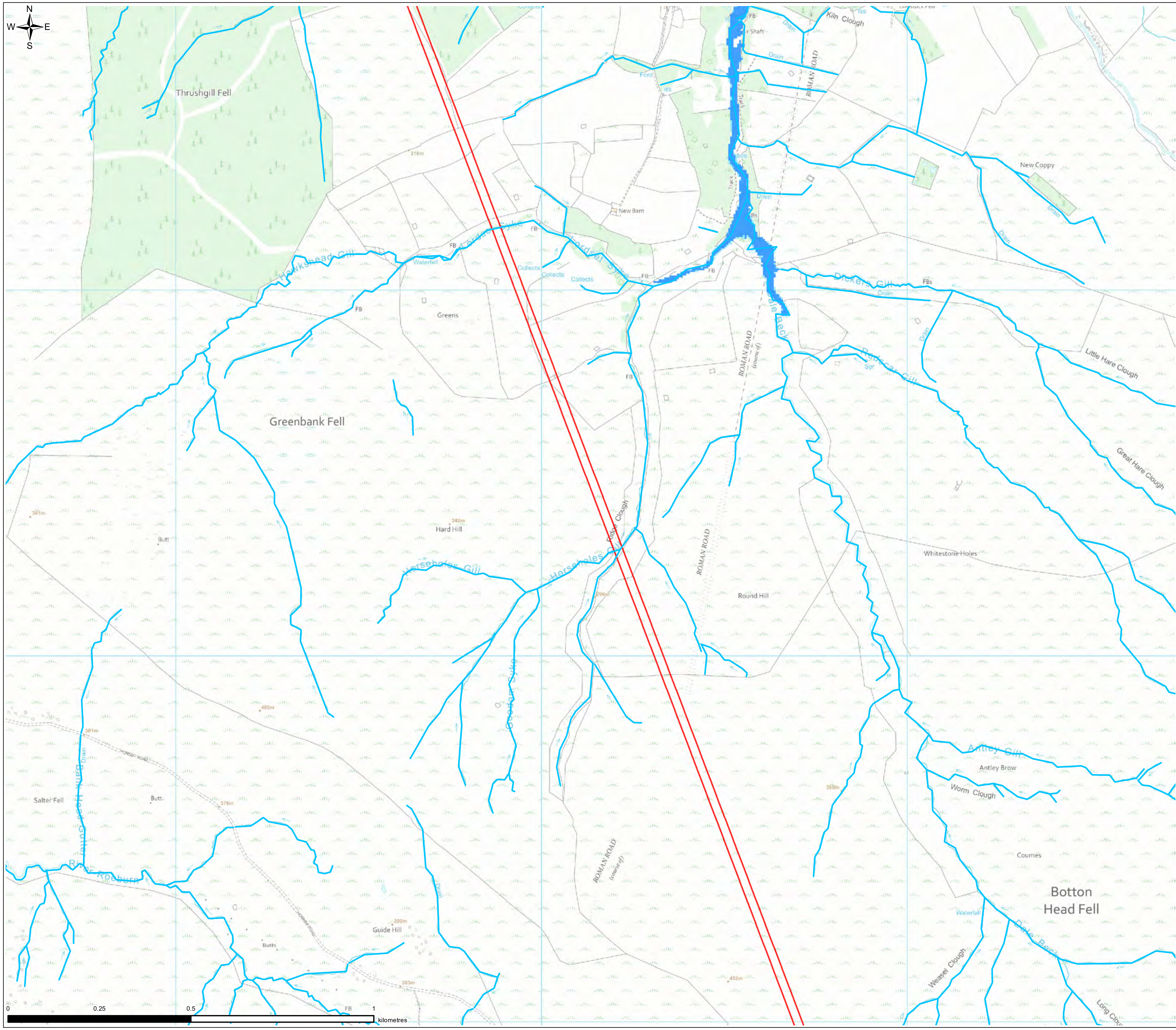
FIGURE 2



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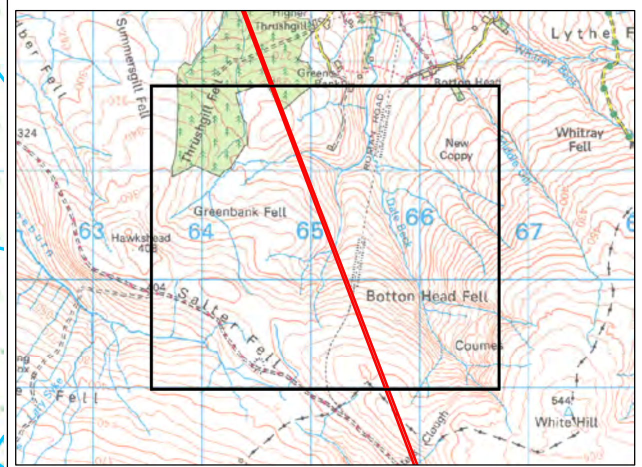

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FLUVIAL FLOOD RISK
PAGE 3 OF 7

SCALE	SHEET SIZE
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LCC_RVBC-BO-FIG-FRA-002	0

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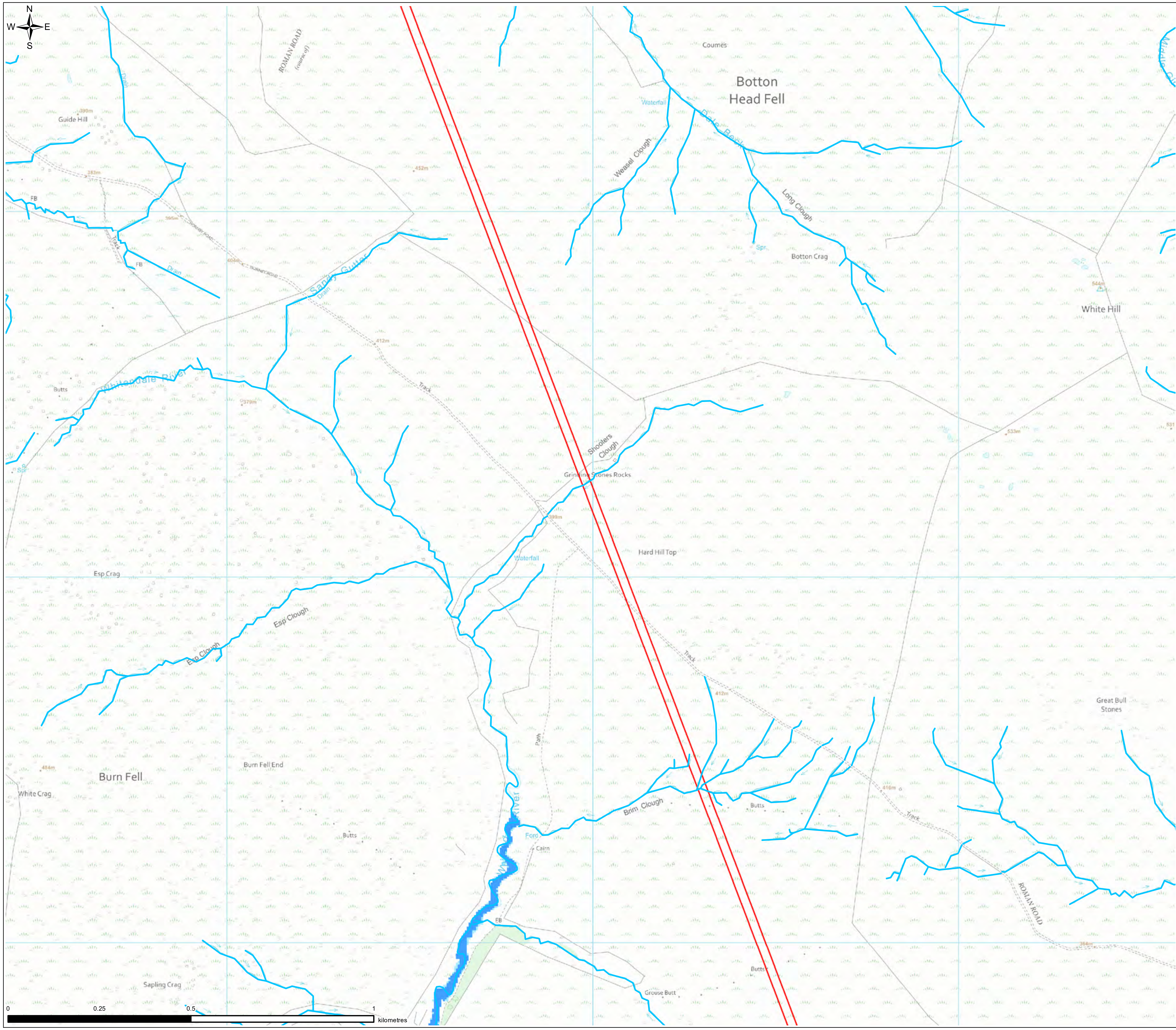

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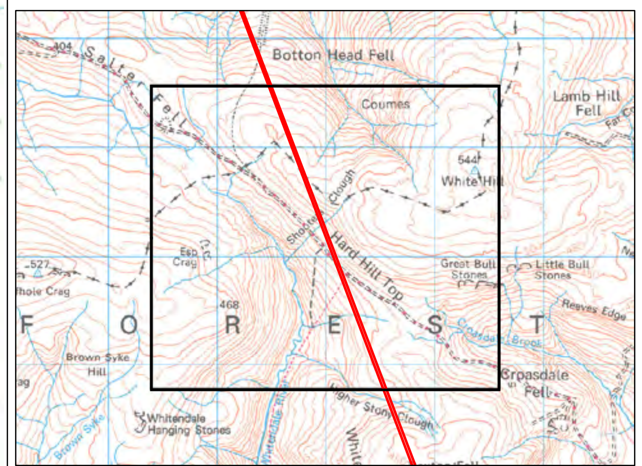

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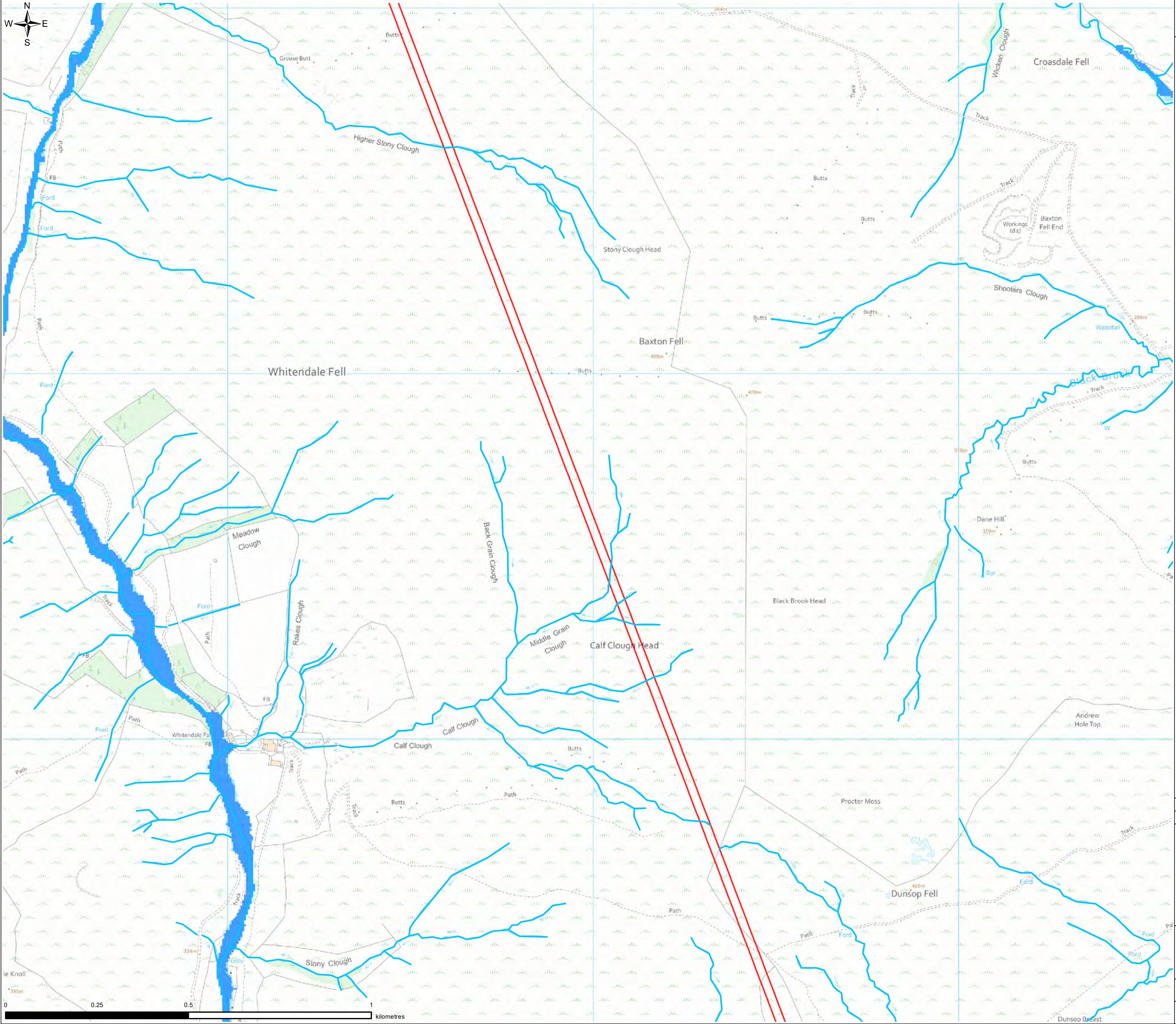
FLUVIAL FLOOD RISK
PAGE 4 OF 7

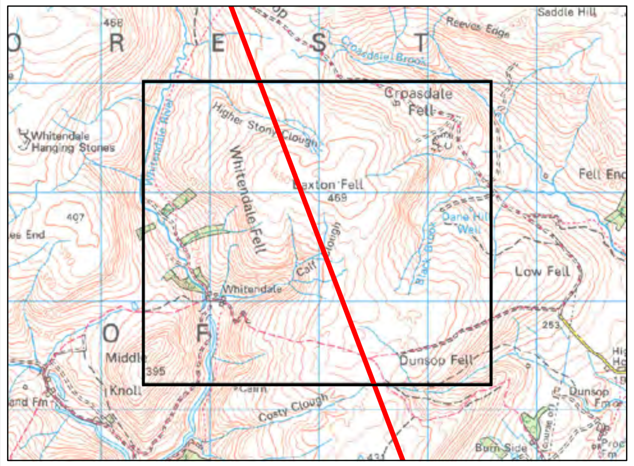
SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-002	0

FIGURE 2



Legend

- Planning Application Boundary
- Watercourses
- Flood Zone 3
- Flood Zone 2



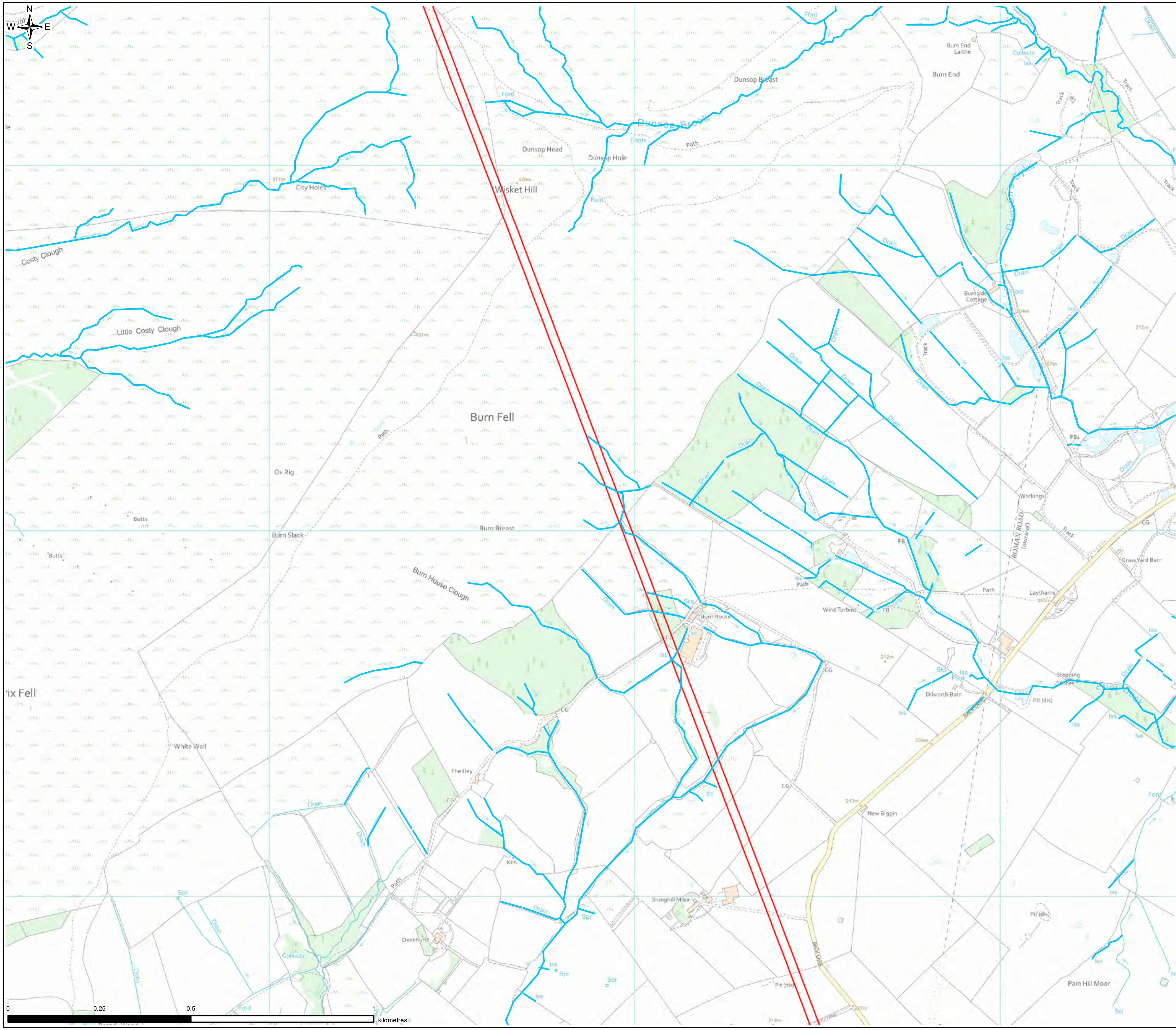
VERSION	AUTH	CHKD	CI	REASON FOR ISSUE	DATE
0	SP	CD	CI	Initial Issue	14/05/2021

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
FLUVIAL FLOOD RISK
PAGE 5 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-002	0

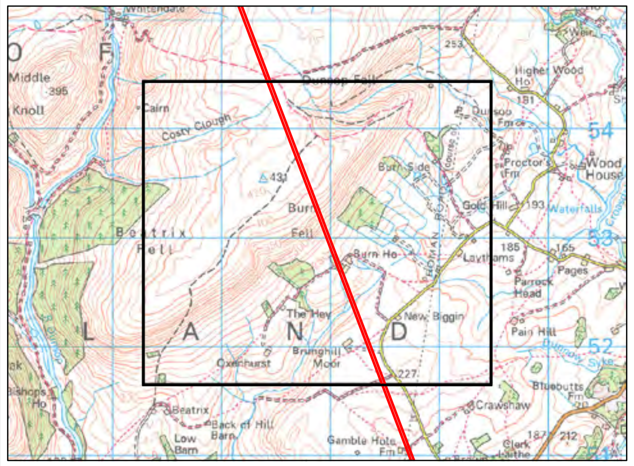
FIGURE 2



Legend

Planning Application Boundary

Watercourses



0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

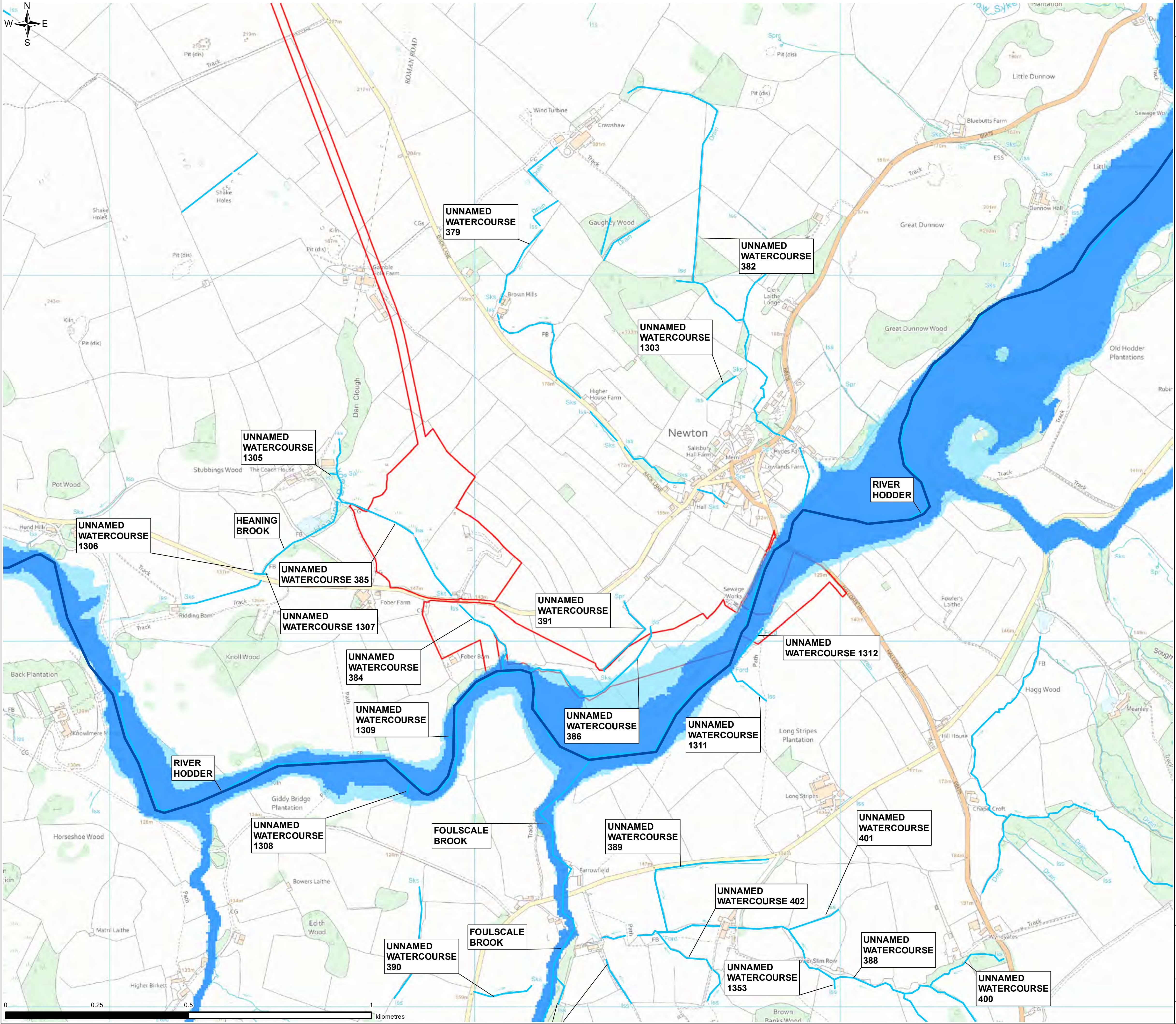
United Utilities

Water for the North West

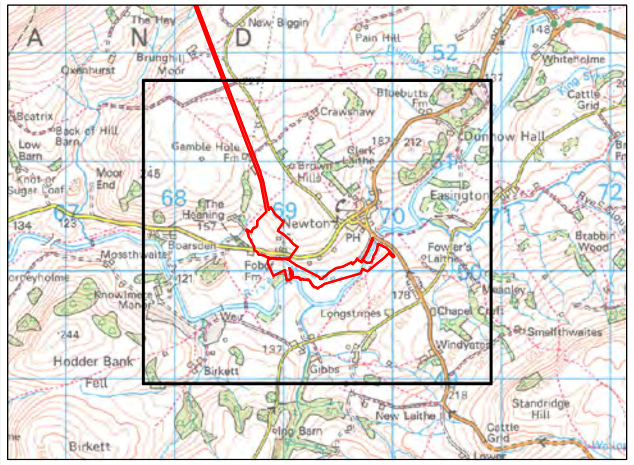
UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
FLUVIAL FLOOD RISK
PAGE 6 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-002	0

FIGURE 2



Legend
- Planning Application Boundary
- Environment Agency Main Rivers
- Watercourses
- Flood Zone 3
- Flood Zone 2



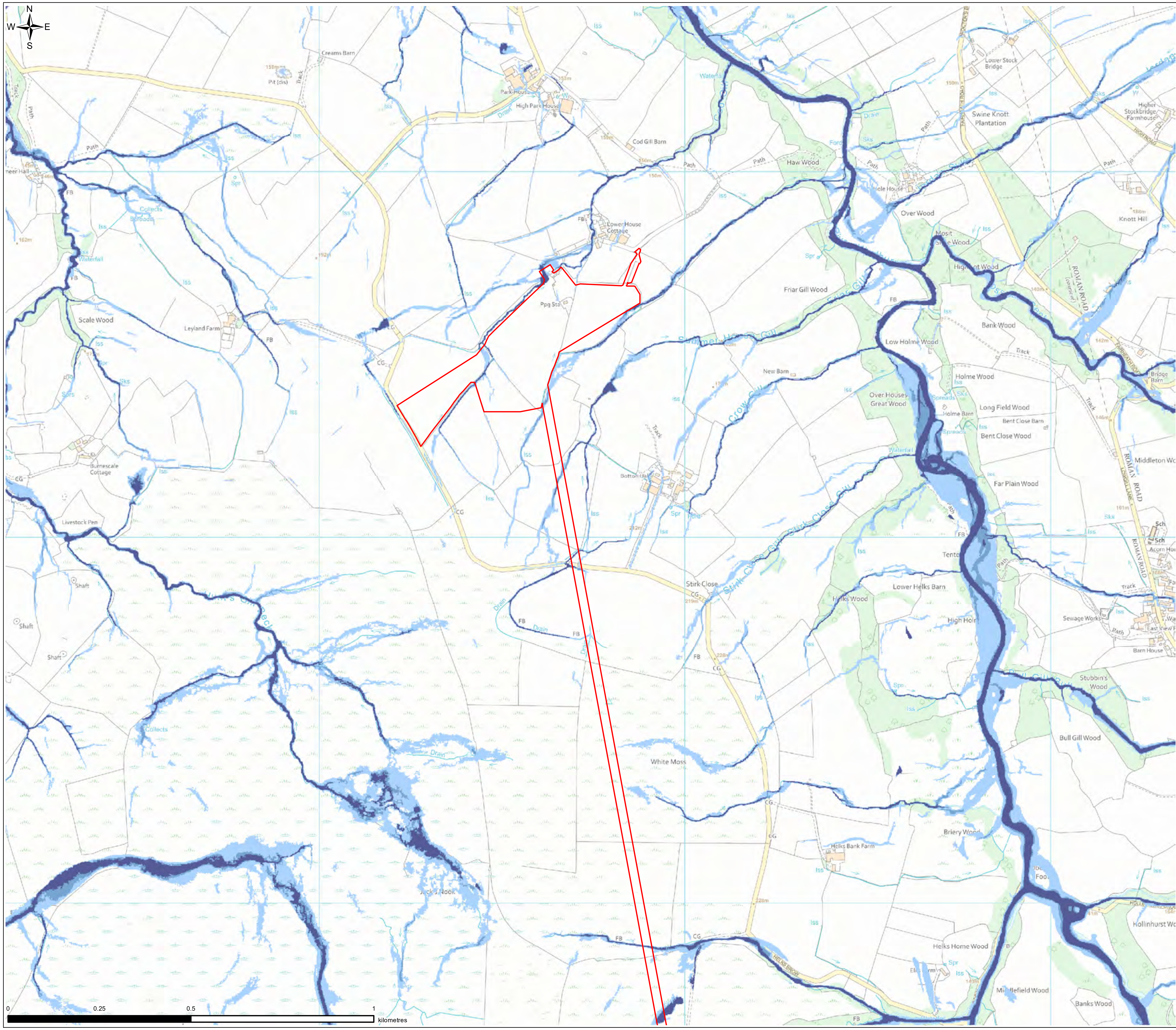
0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
FLUVIAL FLOOD RISK
PAGE 7 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-002	0

FIGURE 3



Legend

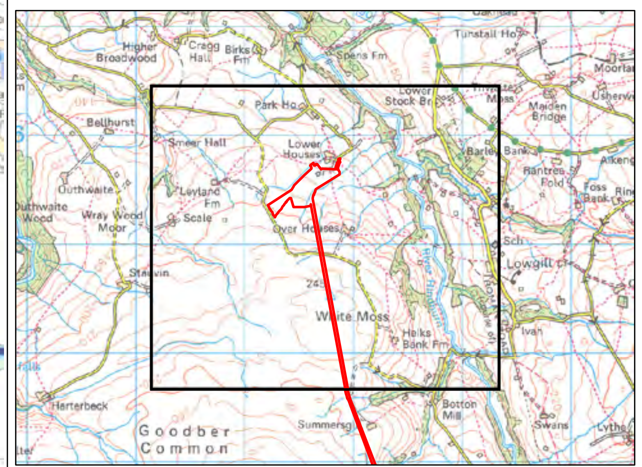
Planning Application Boundary

Risk of Flooding from Surface Water

Surface Water Flood Extent 3.33% AEP

Surface Water Flood Extent 1% AEP

Surface Water Flood Extent 0.1% AEP



0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

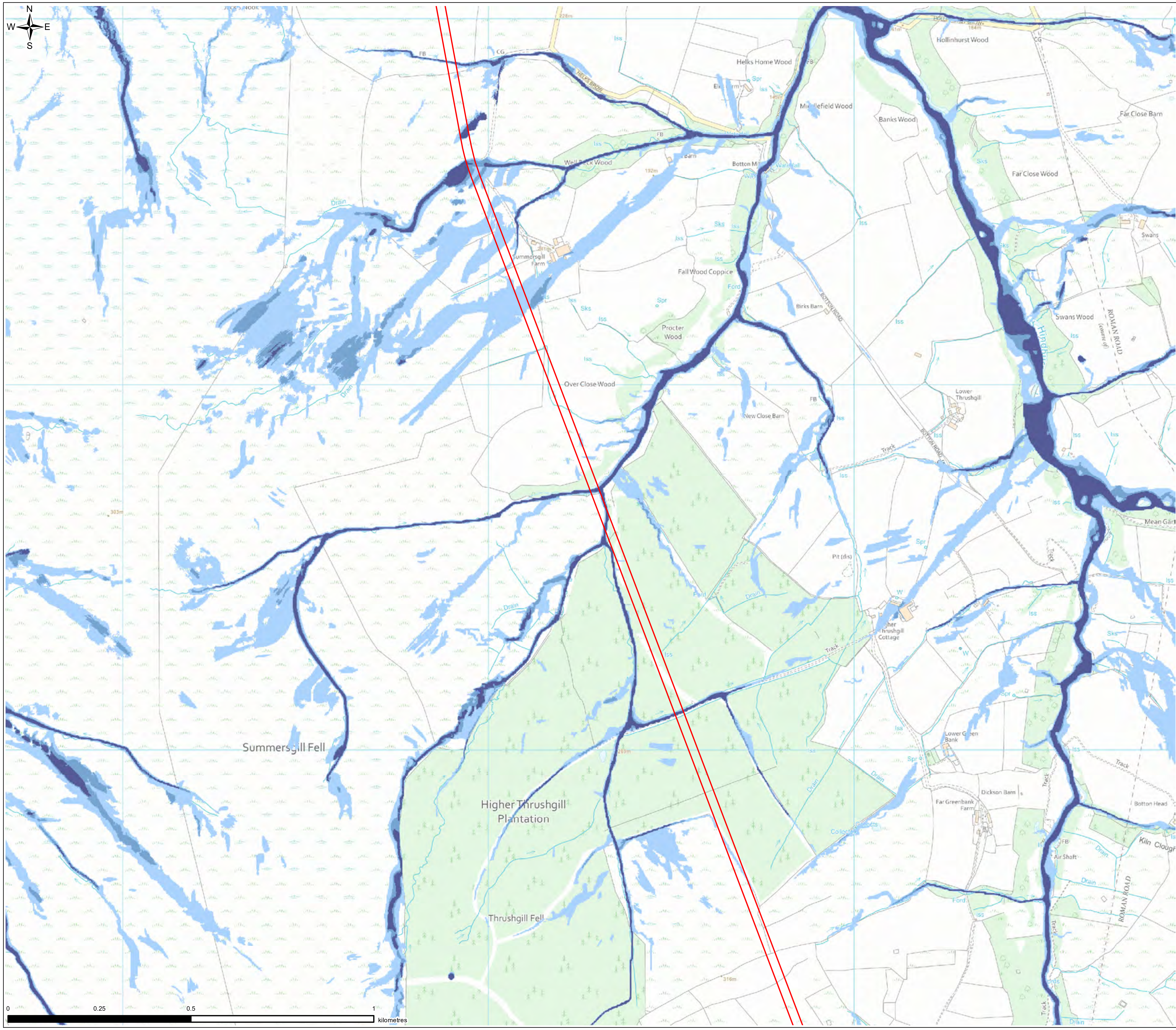
United Utilities

Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
THE RISK OF FLOODING FROM SURFACE WATER MAPPING
PAGE 1 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-003	0

FIGURE 3



Legend

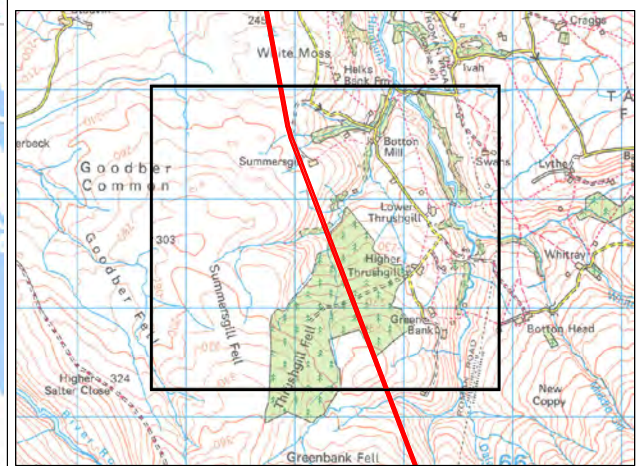
Planning Application Boundary

Risk of Flooding from Surface Water

Surface Water Flood Extent 3.33% AEP

Surface Water Flood Extent 1% AEP

Surface Water Flood Extent 0.1% AEP



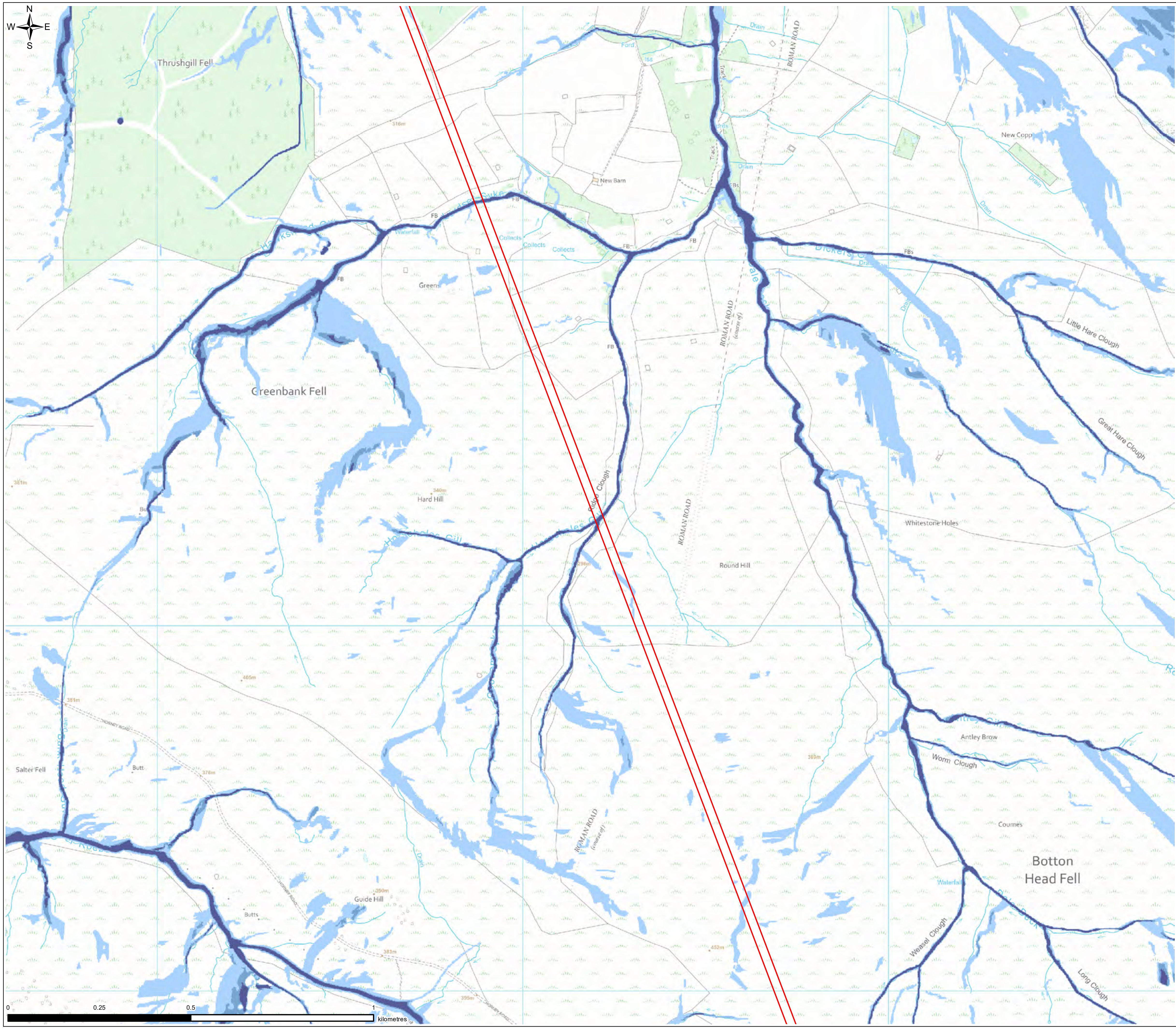
0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
THE RISK OF FLOODING FROM SURFACE WATER MAPPING
PAGE 2 OF 7

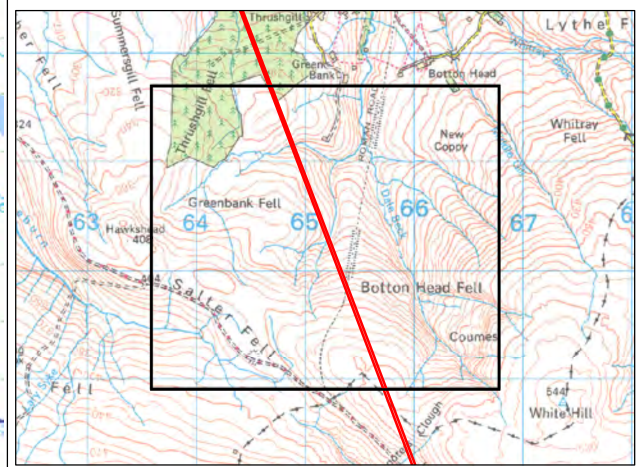
SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-003	0

FIGURE 3



Legend

Planning Application Boundary	
Risk of Flooding from Surface Water	
Surface Water Flood Extent 3.33% AEP	
Surface Water Flood Extent 1% AEP	
Surface Water Flood Extent 0.1% AEP	



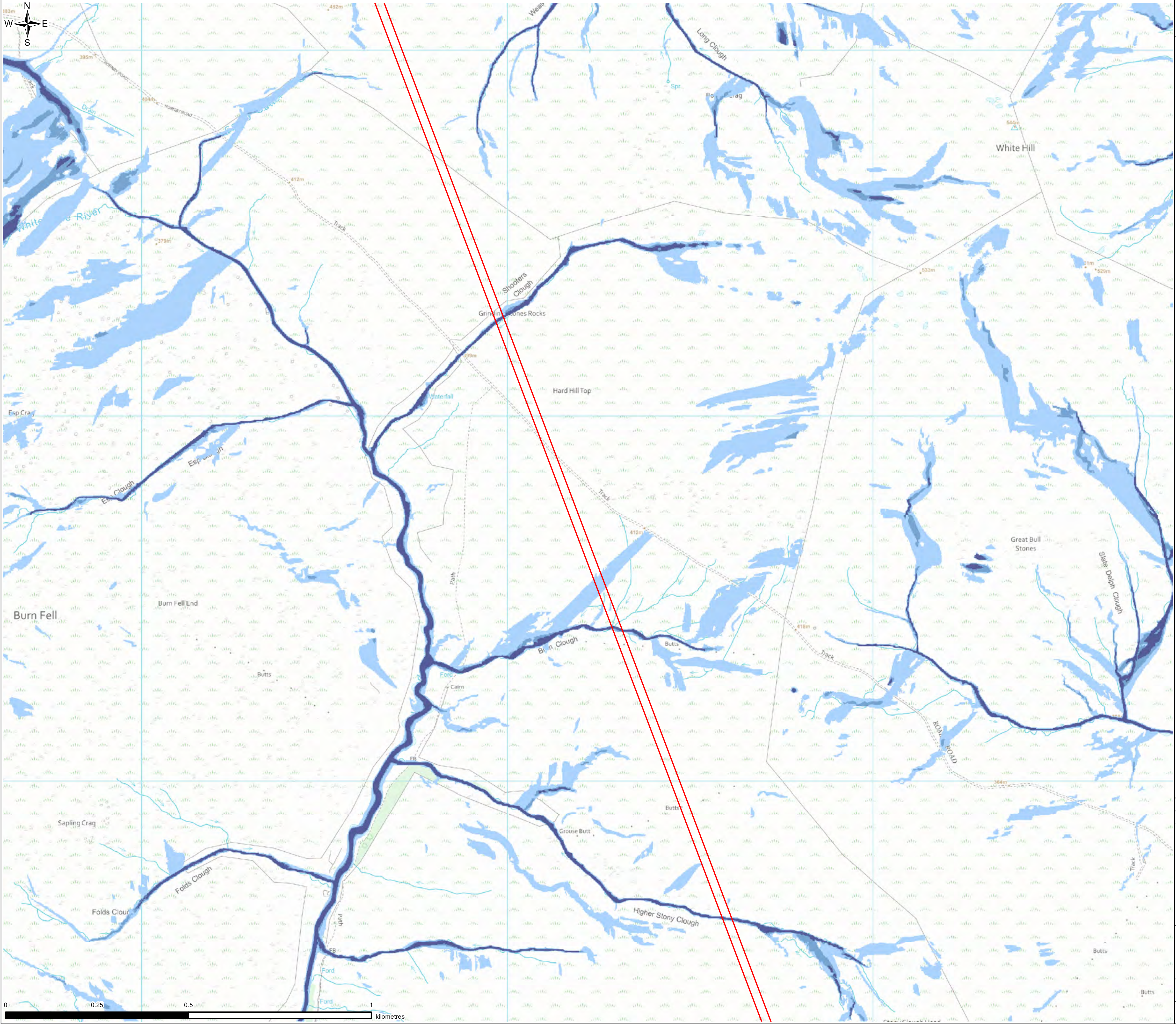
0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
THE RISK OF FLOODING FROM SURFACE WATER MAPPING
PAGE 3 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-003	0

FIGURE 3



Legend

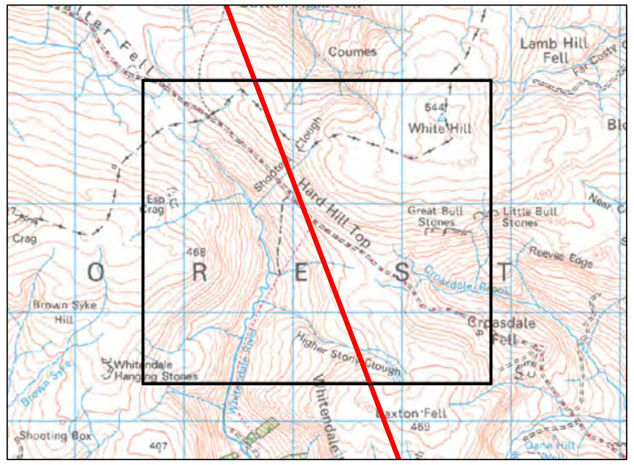
Planning Application Boundary

Risk of Flooding from Surface Water

Surface Water Flood Extent 3.33% AEP

Surface Water Flood Extent 1% AEP

Surface Water Flood Extent 0.1% AEP



0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
THE RISK OF FLOODING FROM SURFACE WATER MAPPING
PAGE 4 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-003	0

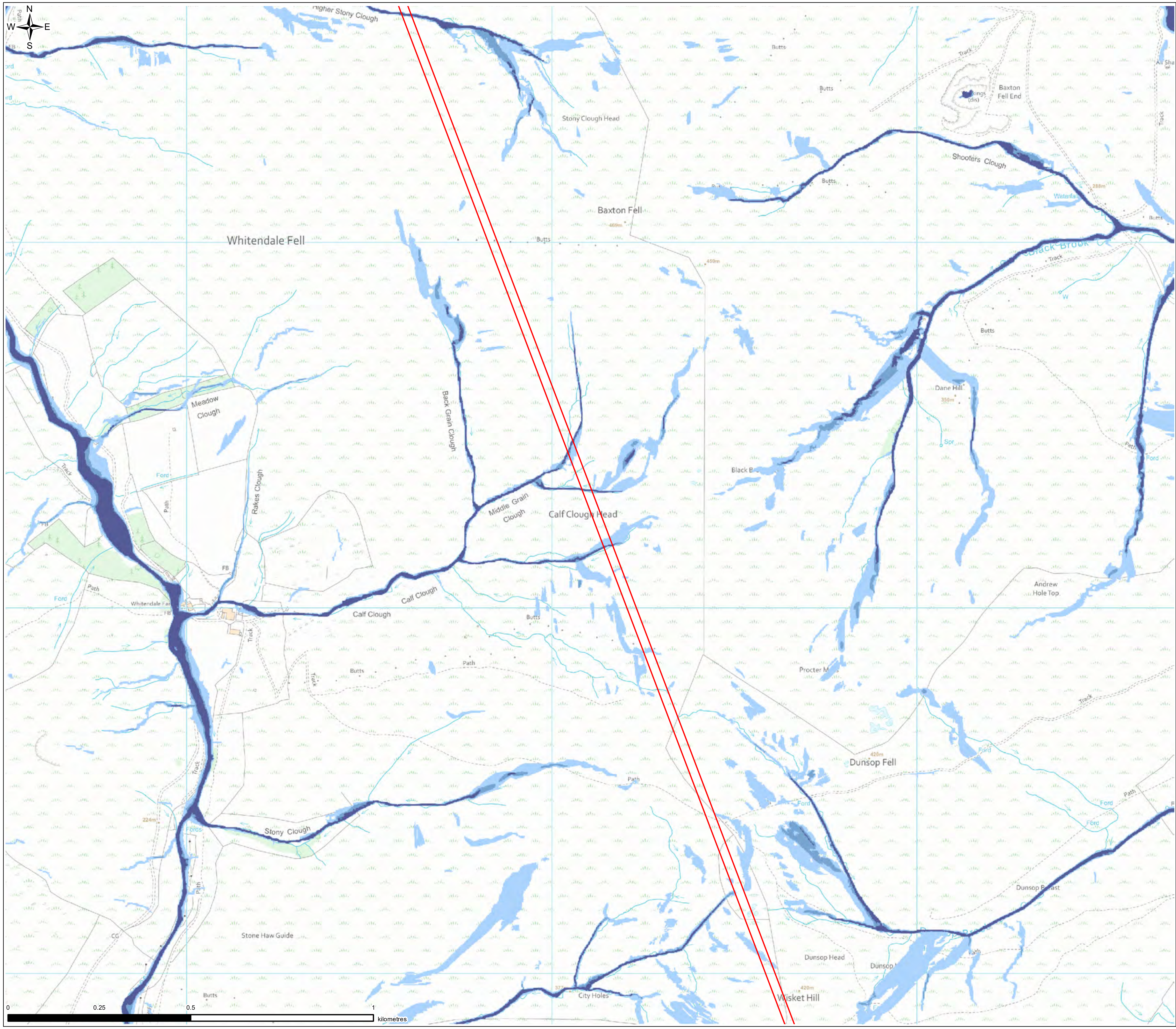


FIGURE 3

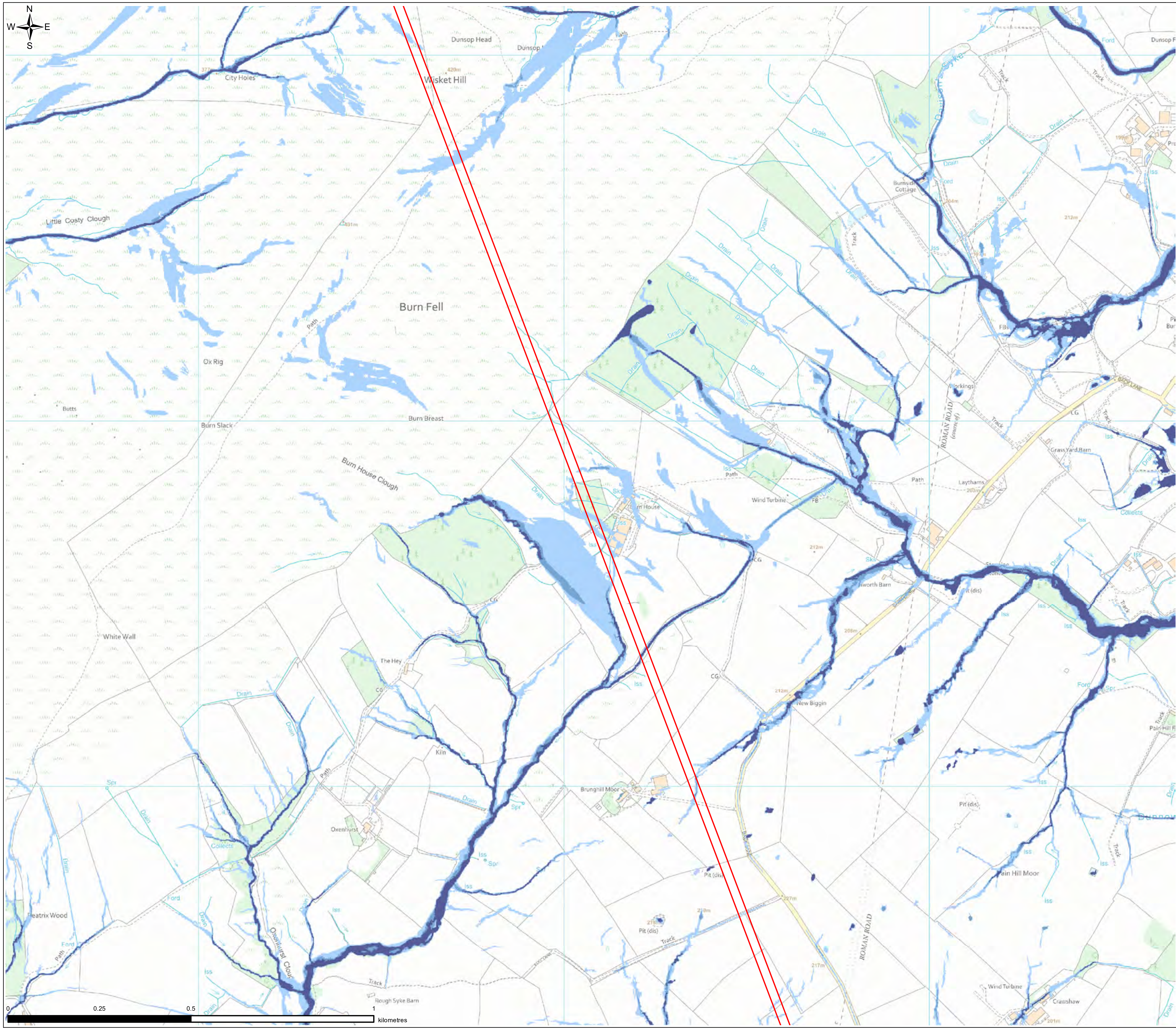
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE
0	SP	CD	CI	Initial Issue	14/05/2021

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
THE RISK OF FLOODING FROM SURFACE WATER MAPPING
PAGE 5 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-003	0

FIGURE 3



Legend

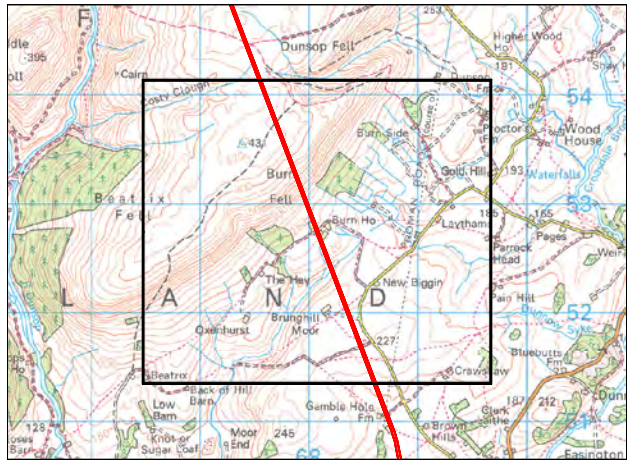
Planning Application Boundary

Risk of Flooding from Surface Water

Surface Water Flood Extent 3.33% AEP

Surface Water Flood Extent 1% AEP

Surface Water Flood Extent 0.1% AEP



0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
THE RISK OF FLOODING FROM SURFACE WATER MAPPING
PAGE 6 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-003	0

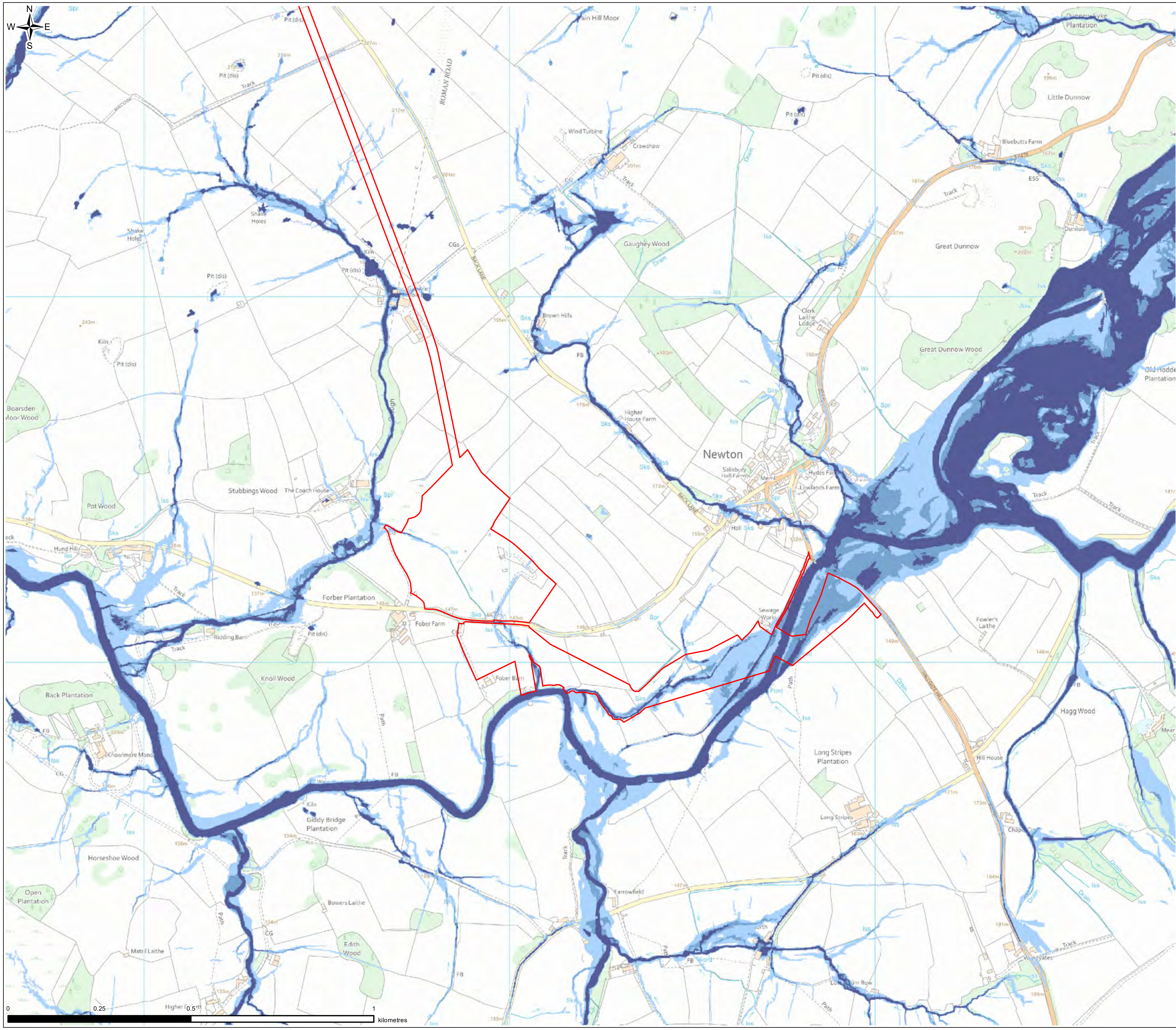


FIGURE 3

Legend

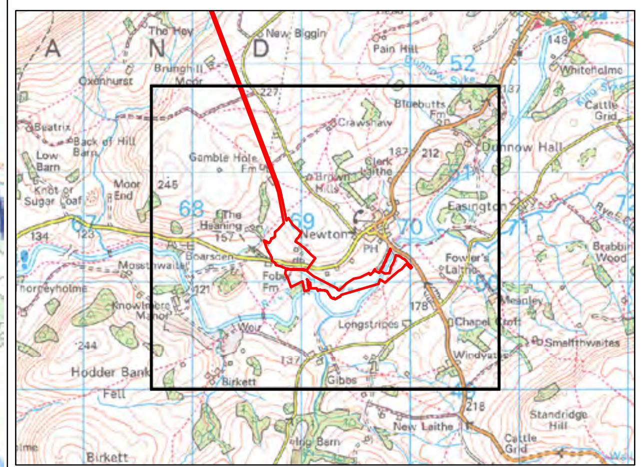
Planning Application Boundary

Risk of Flooding from Surface Water

Surface Water Flood Extent 3.33% AEP

Surface Water Flood Extent 1% AEP

Surface Water Flood Extent 0.1% AEP



VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE
0	SP	CD	CI	Initial Issue	14/05/2021

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
THE RISK OF FLOODING FROM SURFACE WATER MAPPING
PAGE 7 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-003	0

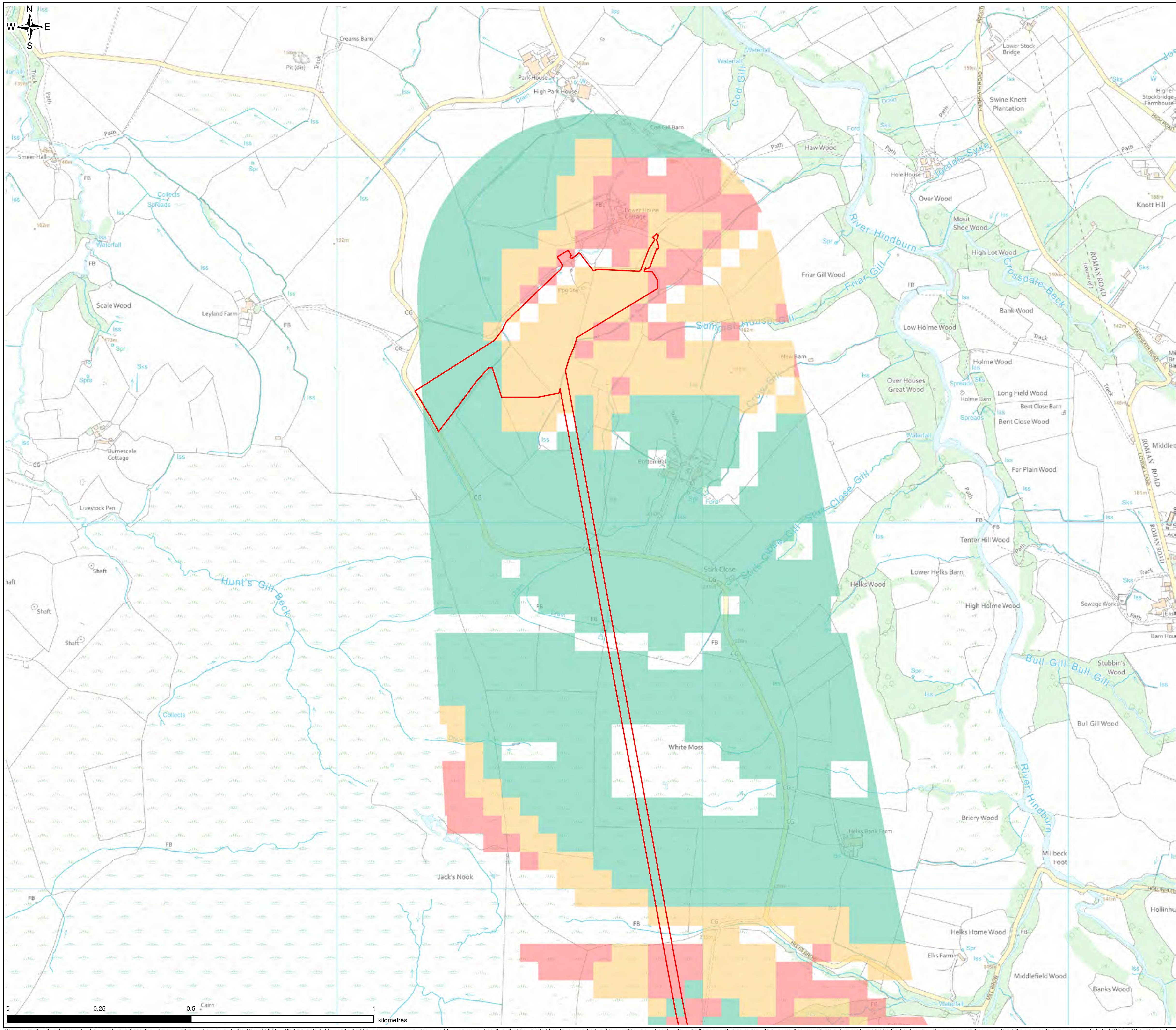


FIGURE 4

Legend

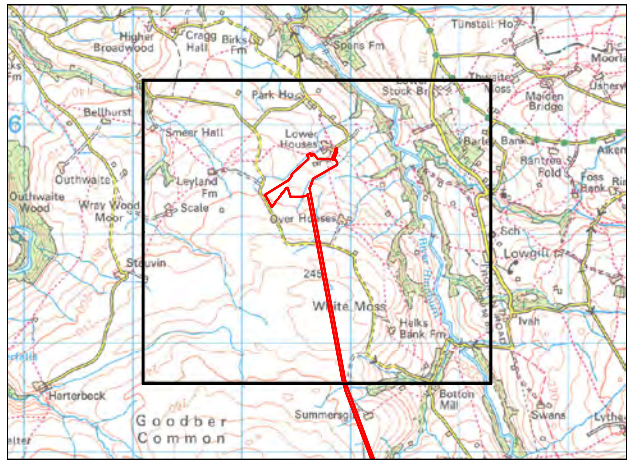
Planning Application Boundary

Groundwater Flooding Susceptibility Areas

Very Low - Low

Moderate - High

Very High



VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE
0	SP	MB	VS-M	Initial Issue	14/05/2021

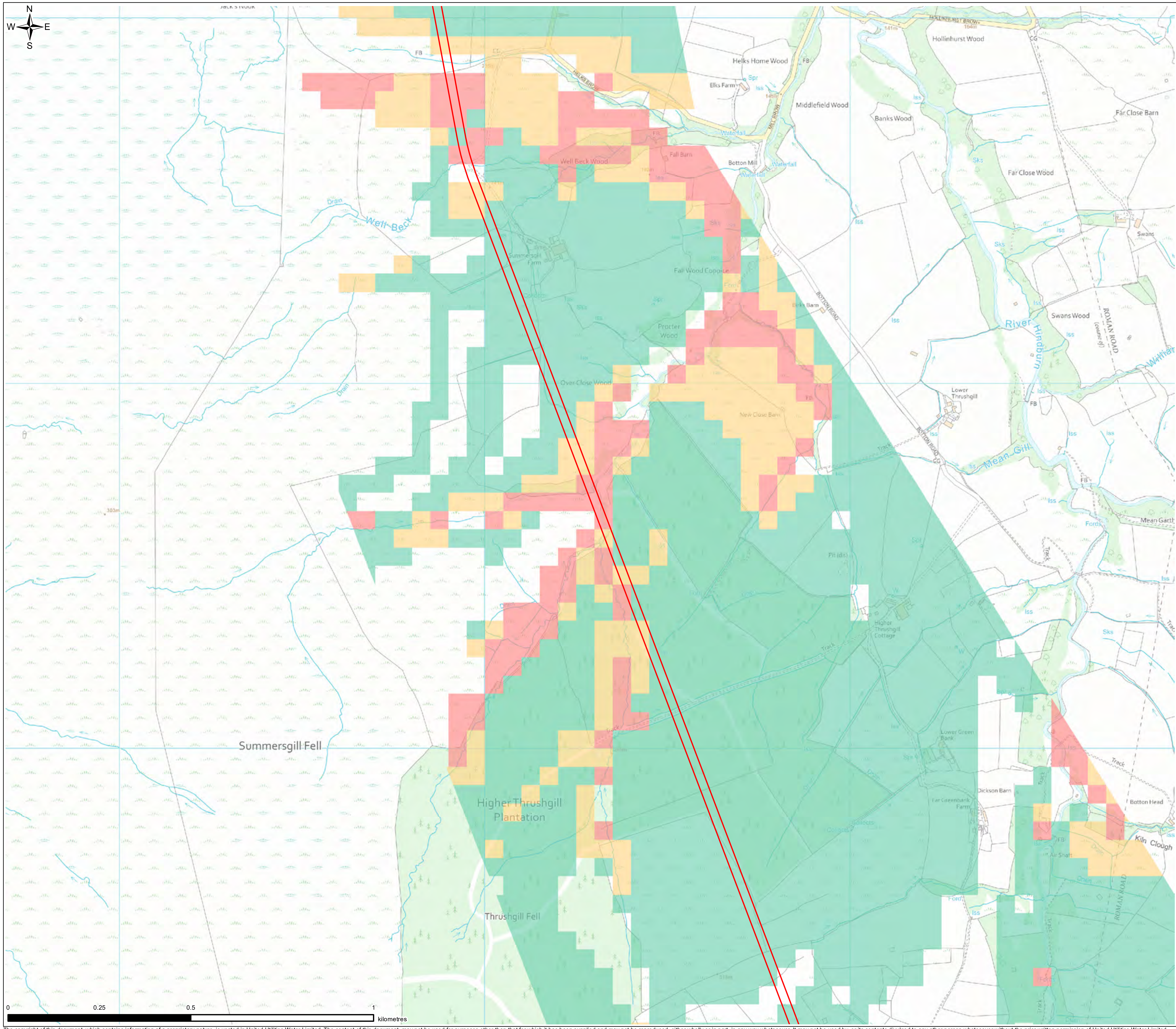
United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING
PAGE 1 OF 7

SCALE	SHEET SIZE
1:10,000	A3

DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-004	0

FIGURE 4



Legend

Planning Application Boundary

Groundwater Flooding Susceptibility Areas

Very Low - Low

Moderate - High

Very High

VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE
0	SP	MB	VS-M	Initial Issue	14/05/2021

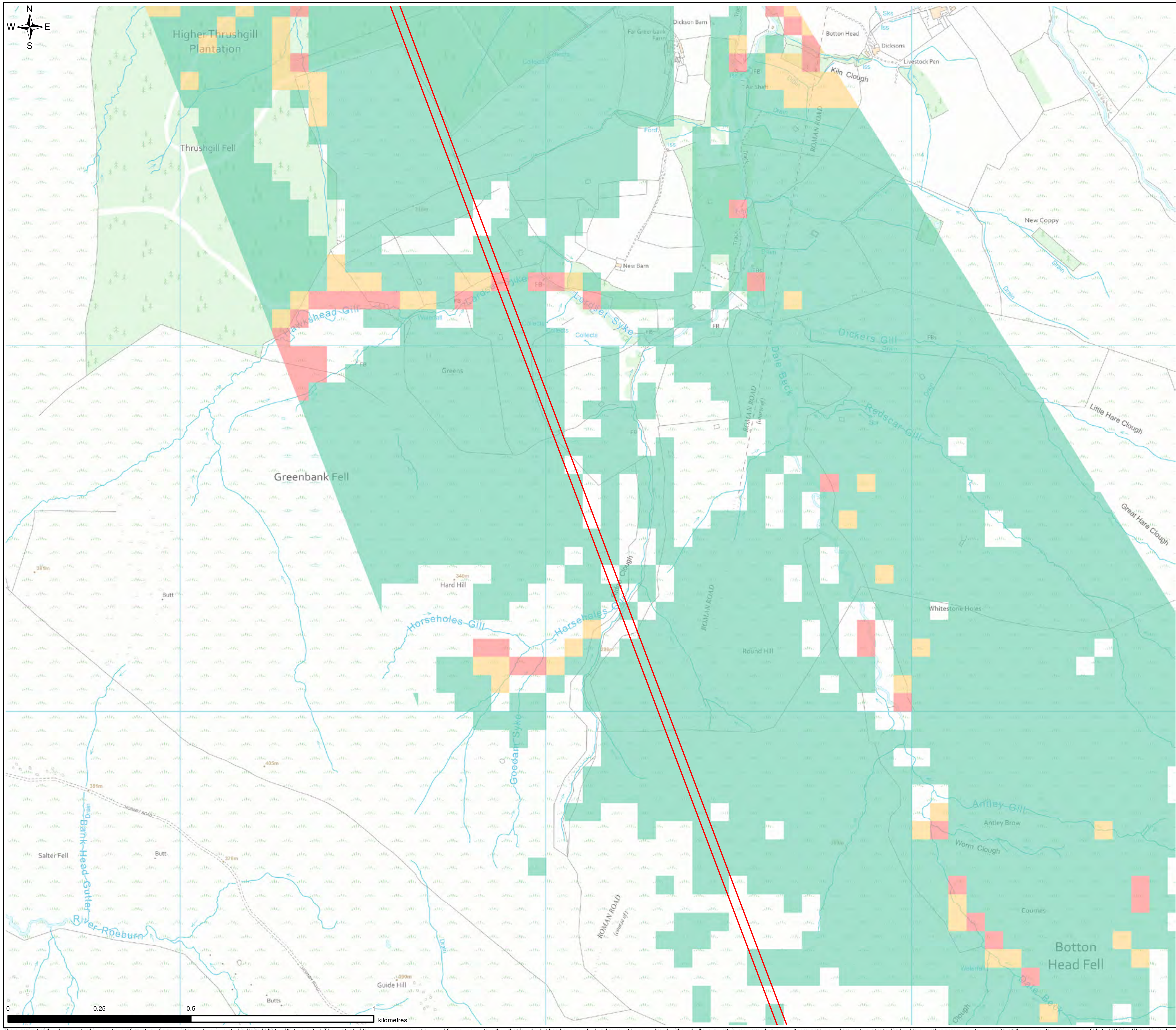
United Utilities

Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING
PAGE 2 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-004	0

FIGURE 4



Legend

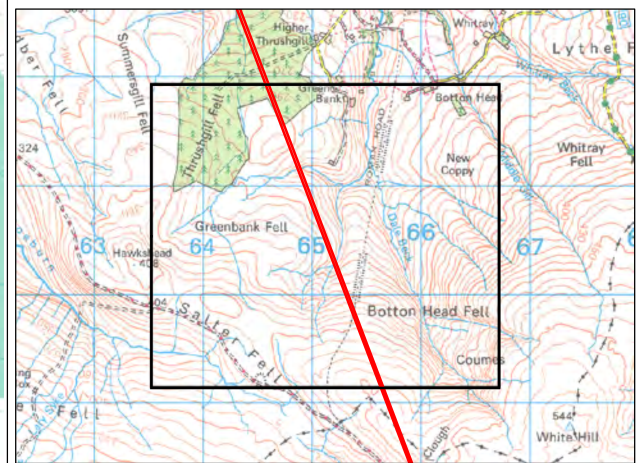
Planning Application Boundary

Groundwater Flooding Susceptibility Areas

Very Low - Low

Moderate - High

Very High



VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE
0	SP	MB	VS-M	Initial Issue	14/05/2021

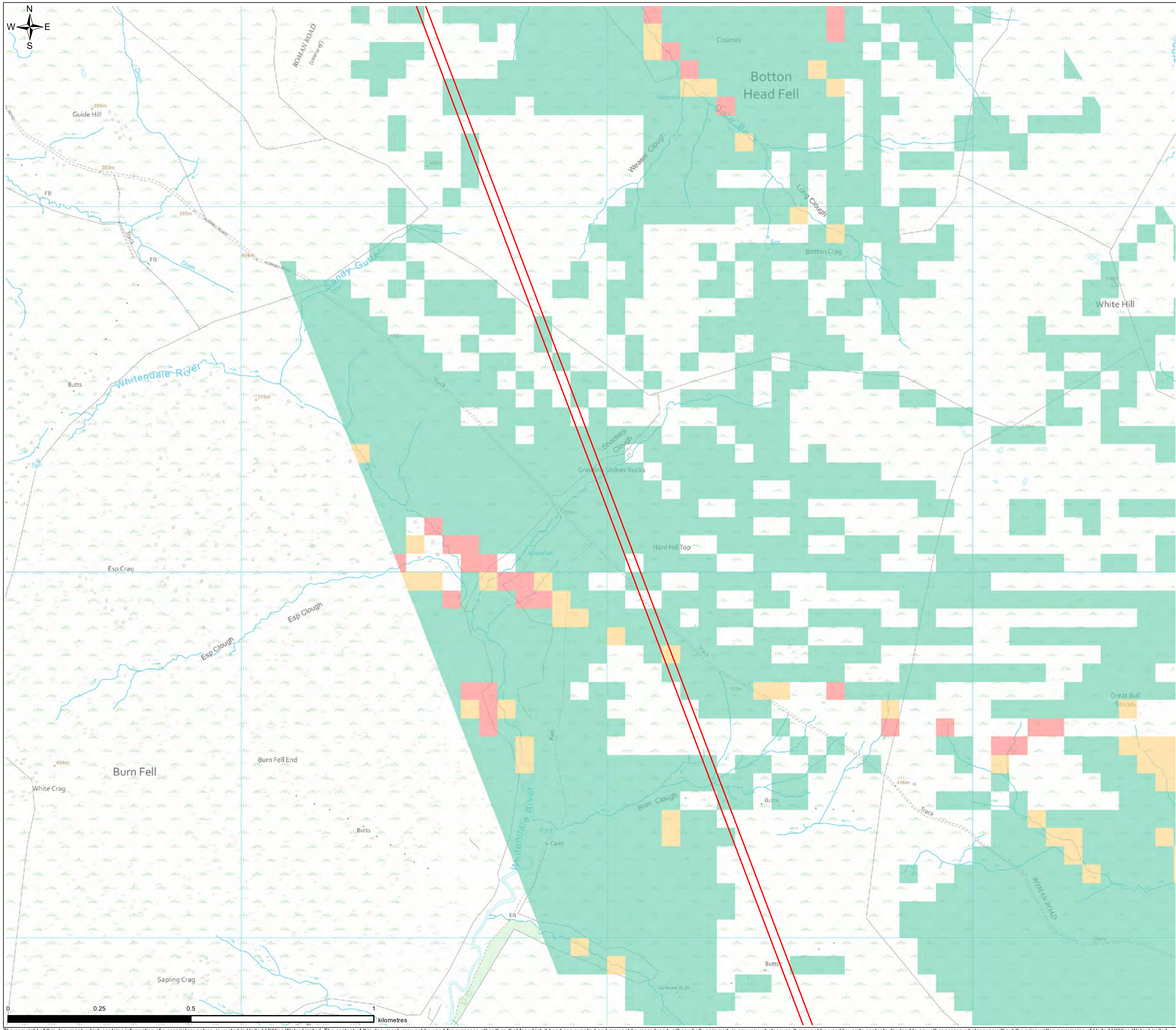
United Utilities

Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING
PAGE 3 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-004	0

FIGURE 4



Legend

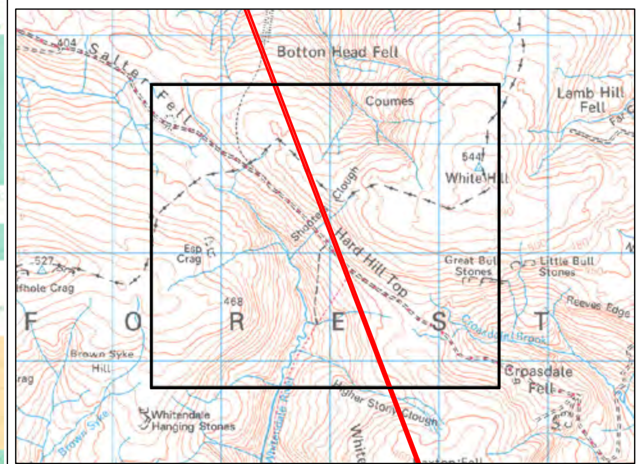
Planning Application Boundary

Groundwater Flooding Susceptibility Areas

Very Low - Low

Moderate - High

Very High



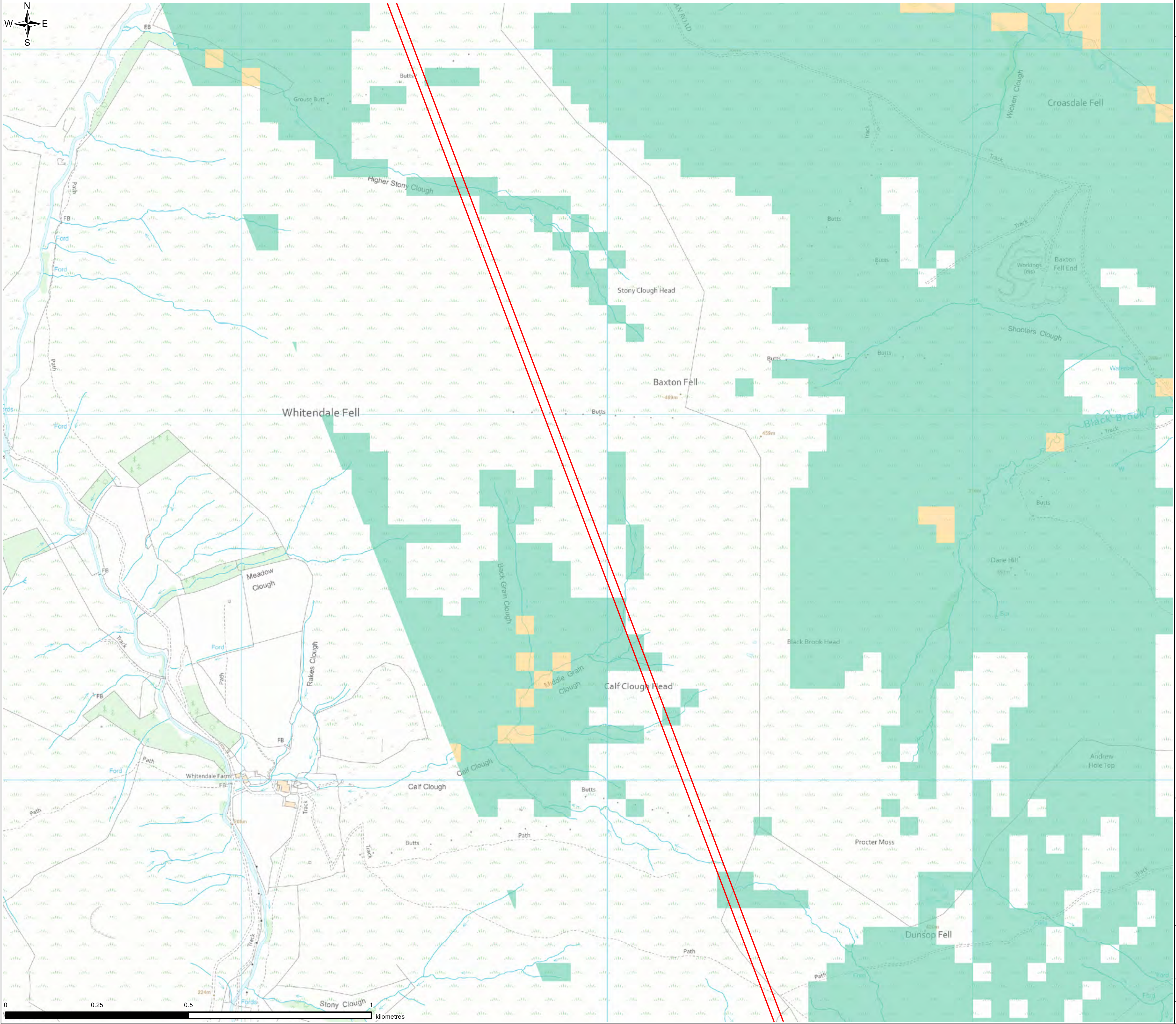
0	SP	MB	VS-M	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING
PAGE 4 OF 7

SCALE 1:10,000	SHEET SIZE A3
DRAWING NUMBER LCC_RVBC-BO-FIG-FRA-004	REVISION 0

FIGURE 4



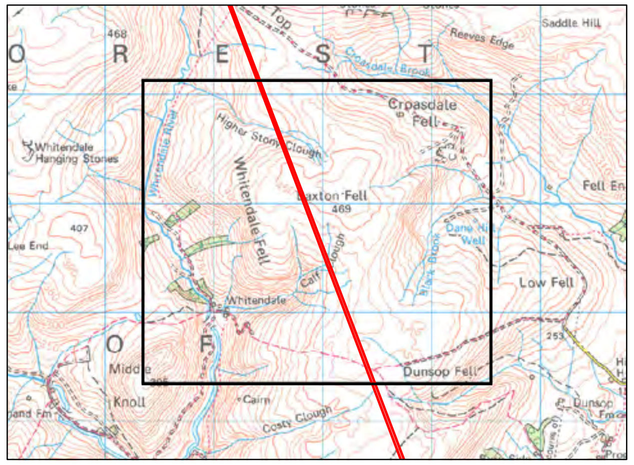
Legend

Planning Application Boundary

Groundwater Flooding Susceptibility Areas

Very Low - Low

Moderate - High



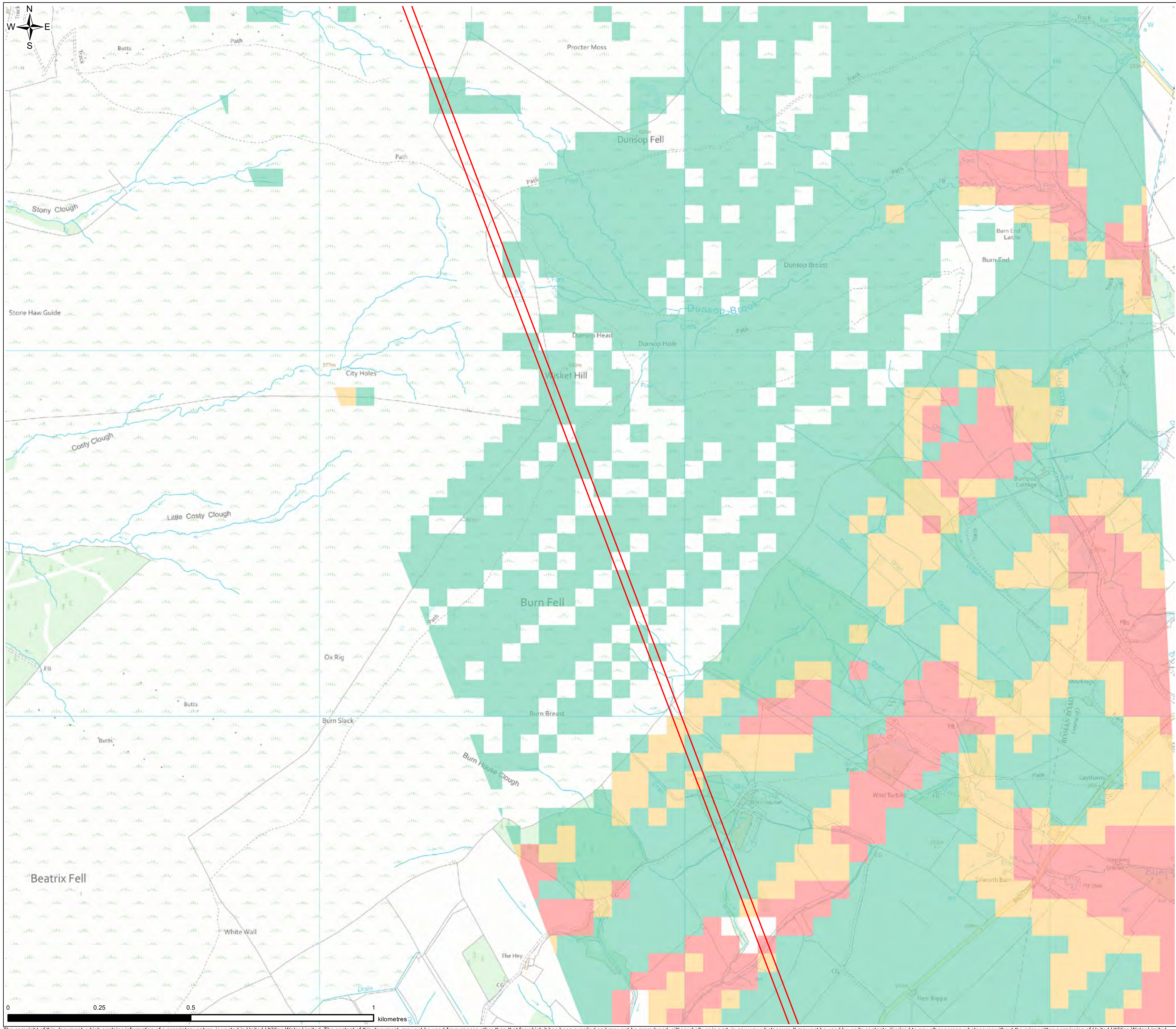
0	SP	MB	VS-M	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING
PAGE 5 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-004	0

FIGURE 4

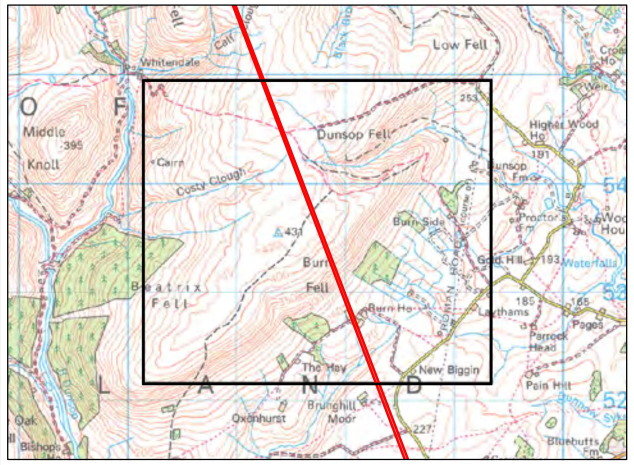


Legend

Planning Application Boundary

Groundwater Flooding Susceptibility Areas

- Very Low - Low
- Moderate - High
- Very High



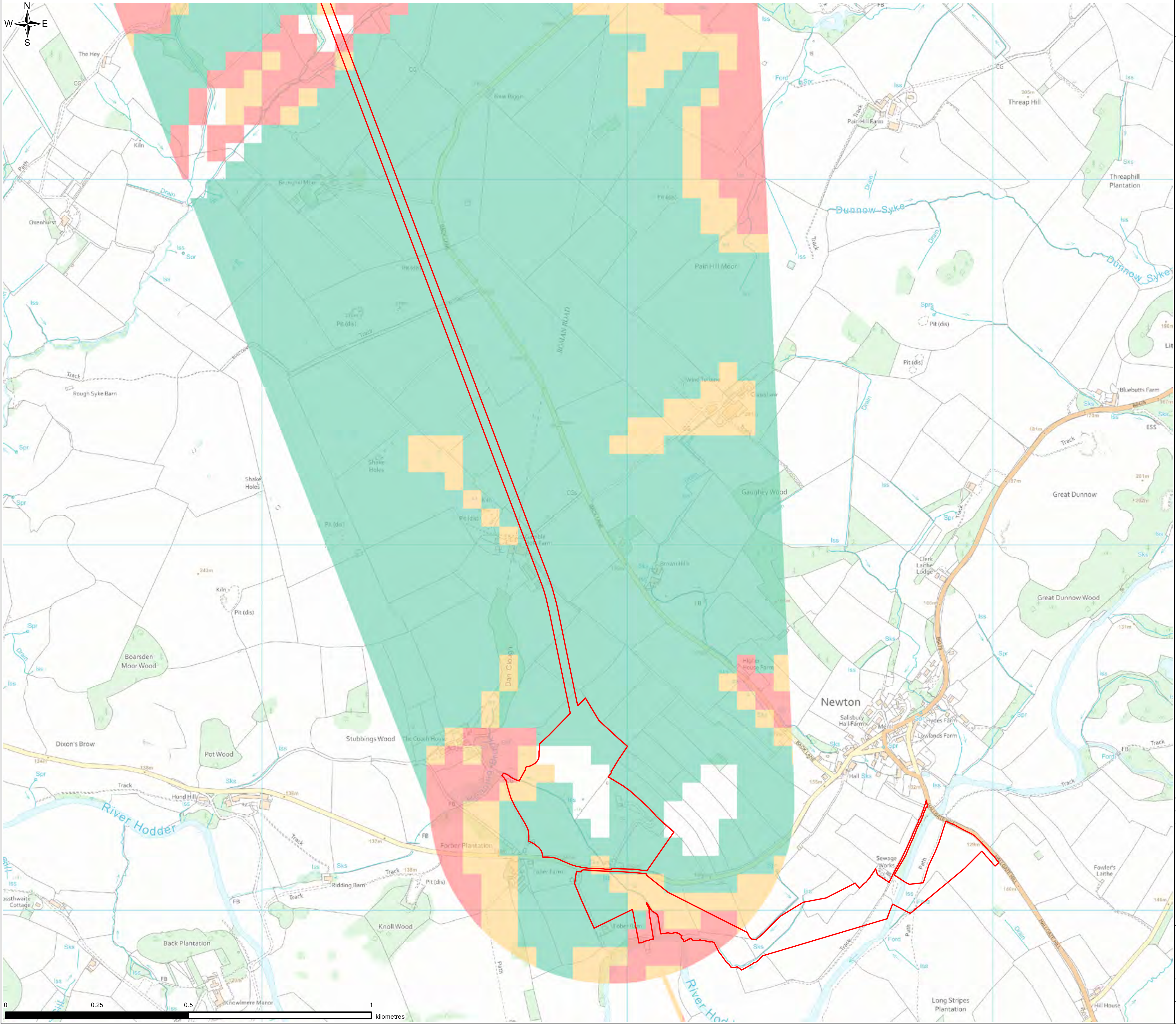
0	SP	MB	VS-M	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING
PAGE 6 OF 7

SCALE	SHEET SIZE
1:10,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-004	0

FIGURE 4

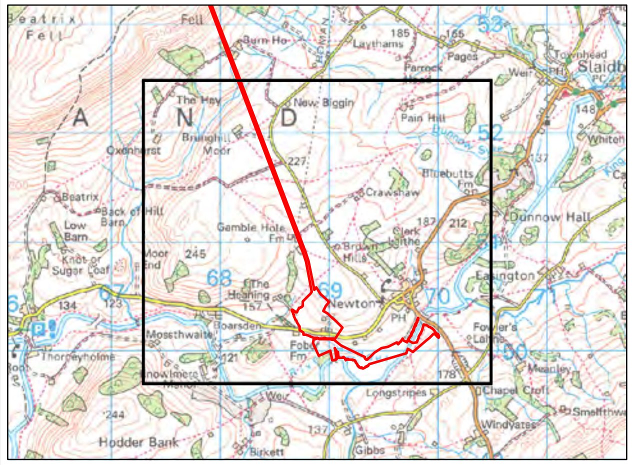


Legend

(red outline)	Planning Application Boundary

Groundwater Flooding Susceptibility Areas

(green)	Very Low - Low
(orange)	Moderate - High
(pink)	Very High



VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE
0	SP	MB	VS-M	Initial Issue	14/05/2021

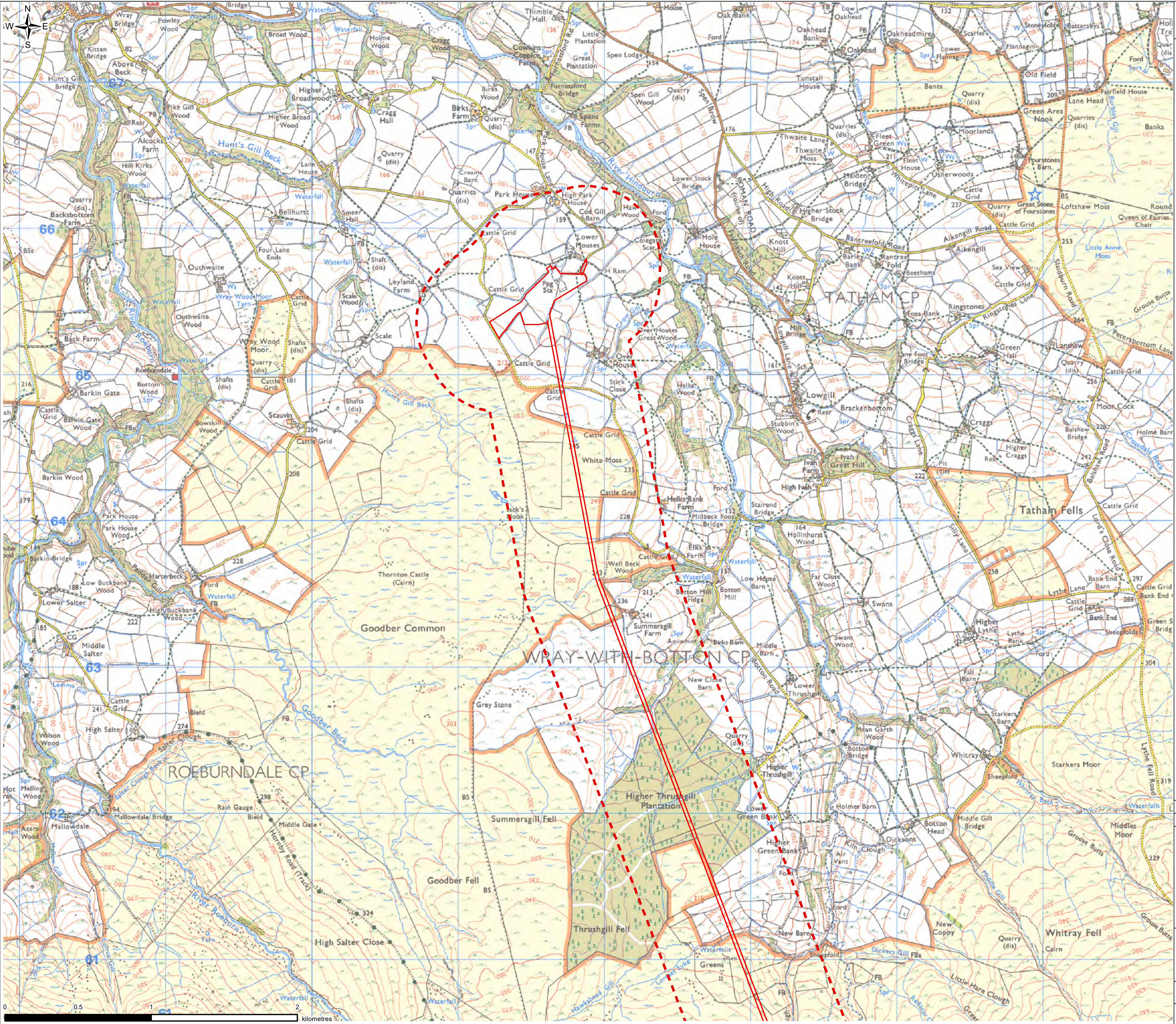
United Utilities

Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING
PAGE 7 OF 7

SCALE 1:10,000	SHEET SIZE A3
DRAWING NUMBER LCC_RVBC-BO-FIG-FRA-004	REVISION 0

FIGURE 5

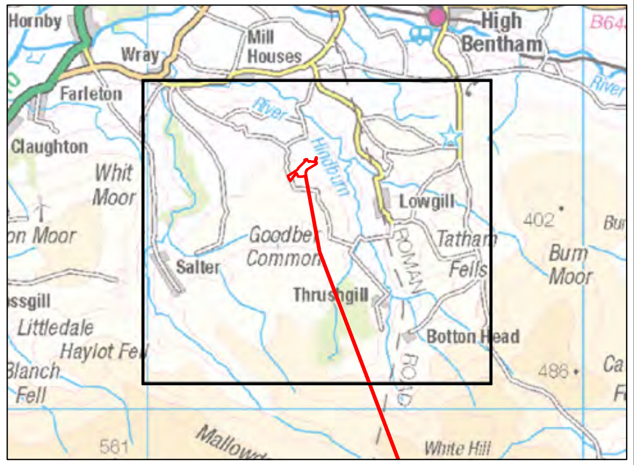


Legend

- Planning Application Boundary
- 500m Assessment Area

Risk of Flooding from Reservoirs

- Maximum Extent of Flooding



0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
RESERVOIR FLOOD MAP
PAGE 1 OF 3

SCALE 1:25,000	SHEET SIZE A3
DRAWING NUMBER LCC_RVBC-BO-FIG-FRA-005	REVISION 0

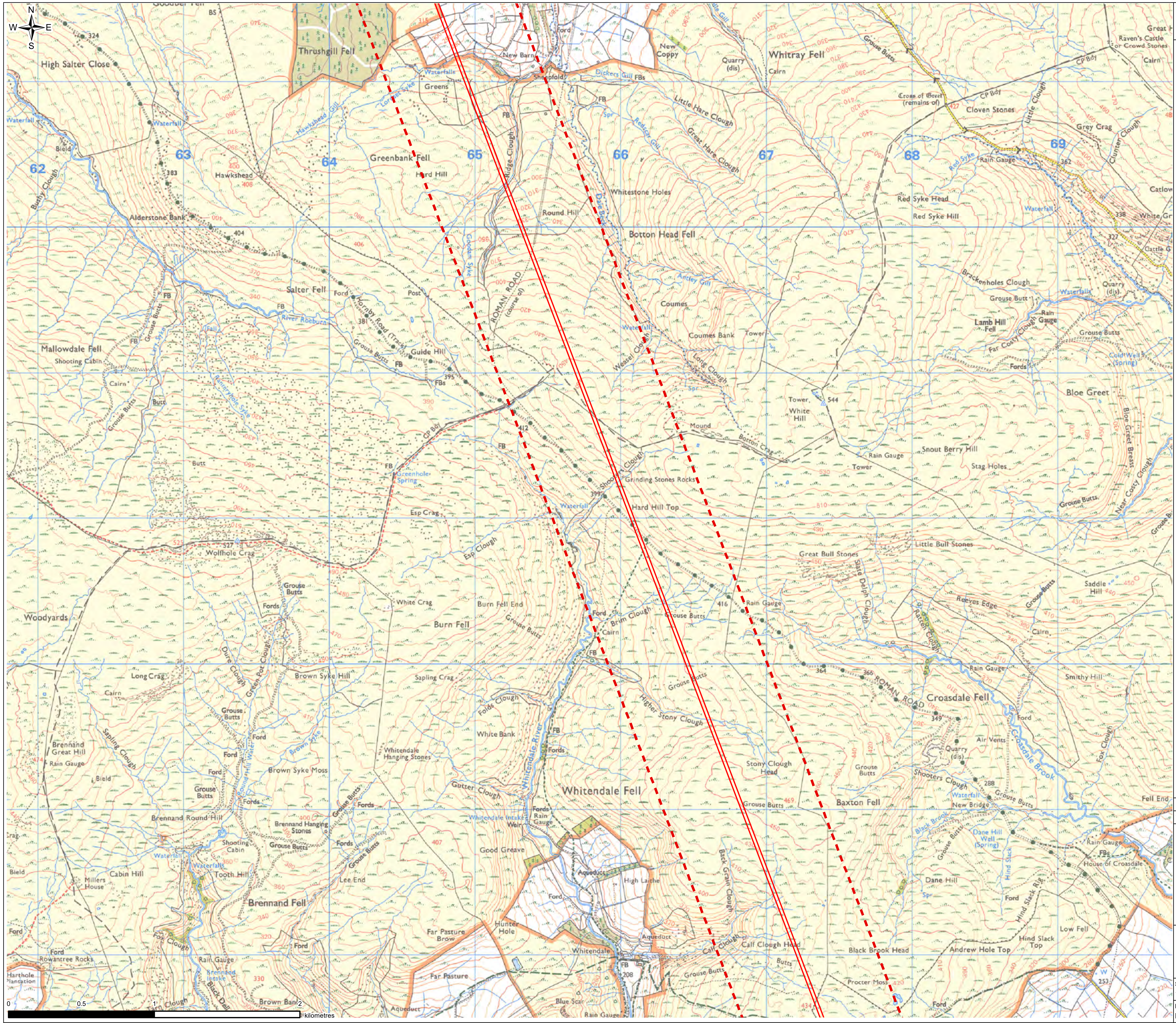


FIGURE 5

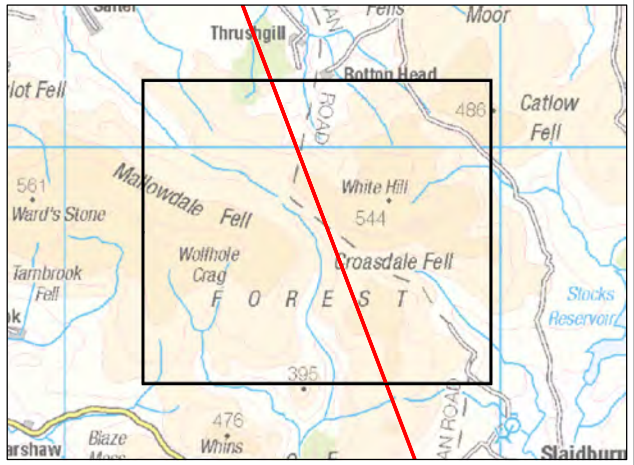
Legend

Planning Application Boundary

500m Assessment Area

Risk of Flooding from Reservoirs

Maximum Extent of Flooding



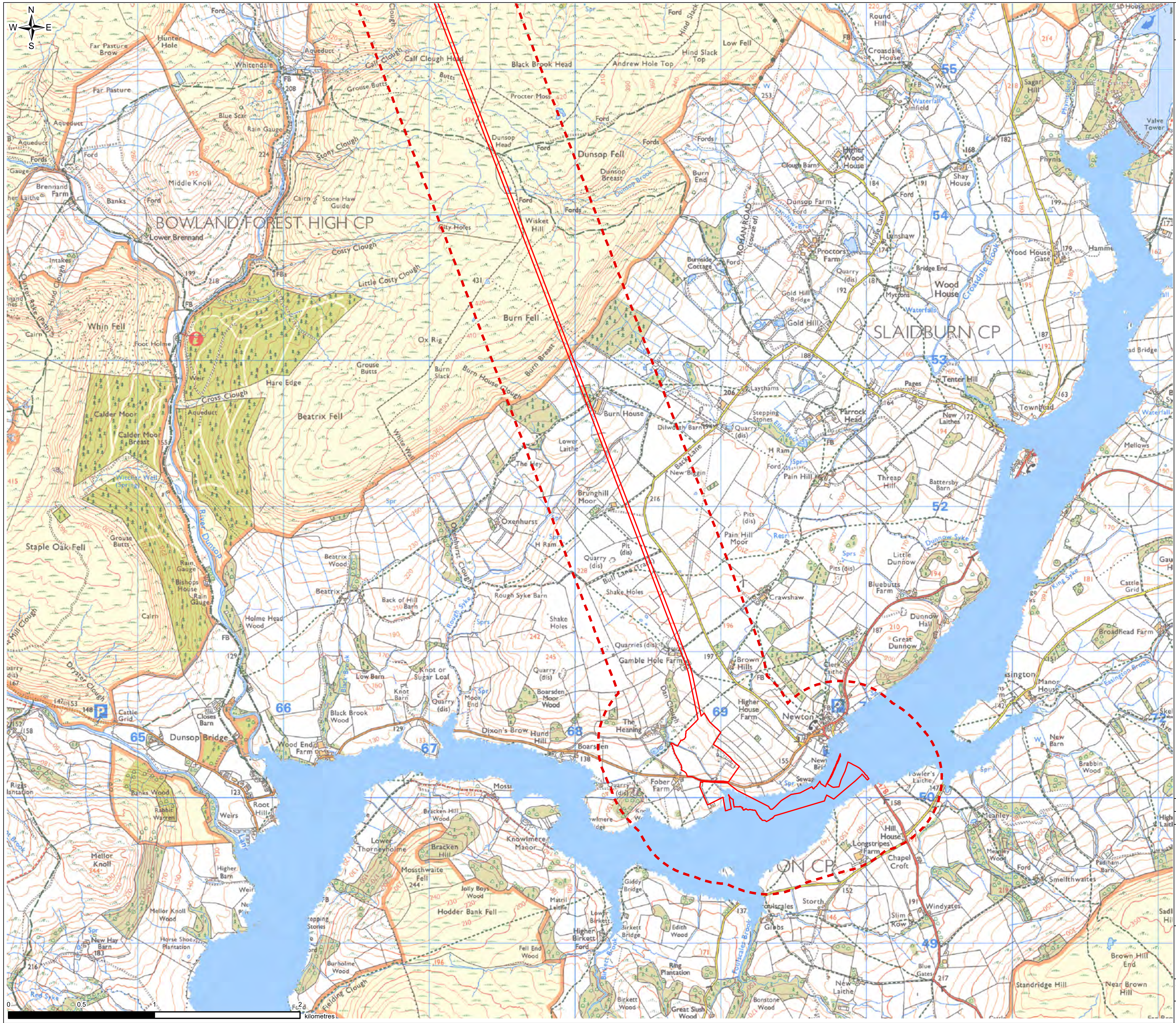
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE
0	SP	CD	CI	Initial Issue	14/05/2021

United Utilities
Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
RESERVOIR FLOOD MAP
PAGE 2 OF 3

SCALE	SHEET SIZE
1:25,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-005	0

FIGURE 5

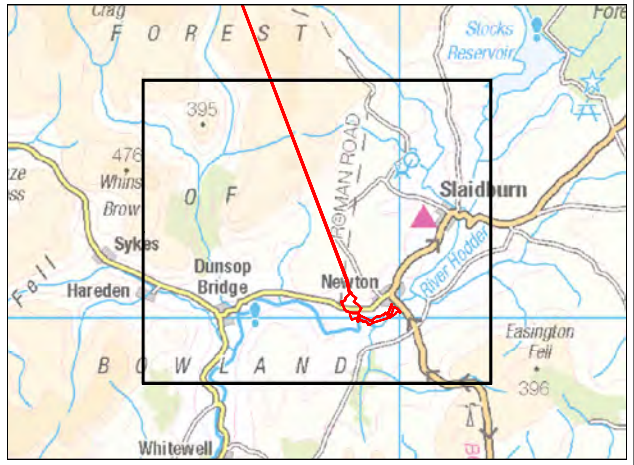


Legend

- Planning Application Boundary
- 500m Assessment Area

Risk of Flooding from Reservoirs

- Maximum Extent of Flooding



0	SP	CD	CI	Initial Issue	14/05/2021
VERSION	AUTH	CHKD	REVD	REASON FOR ISSUE	DATE

United Utilities

Water for the North West

UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
RESERVOIR FLOOD MAP
PAGE 3 OF 3

SCALE	SHEET SIZE
1:25,000	A3
DRAWING NUMBER	REVISION
LCC_RVBC-BO-FIG-FRA-005	0