Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

Environmental Statement

Volume 4

Appendix 8.1: Flood Risk Assessment

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Water for the North West

Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

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1. Introduction

1.1 Purpose

1) This Flood Risk Assessment (FRA) has been prepared to support the planning application for the Marl Hill Section of the Haweswater Aqueduct Resilience Programme (HARP). The assessment of flood risk has been carried out in combination with the Proposed Marl Hill 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 Marl Hill 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 Marl Hill Section
  - Determine the potential impacts of the Proposed Marl Hill 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 Marl Hill Section, including:
  - 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 Scheme 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 Marl Hill Section

6) At the central section of the aqueduct would be the Proposed Marl Hill Section, located within the administrative boundary of Ribble Valley Borough Council and Lancashire County Council extending from approximately 1.3 km south of Newton-in-Bowland to 1.3 km north of Waddington.

7) The existing aqueduct between the Hodder multi-line siphon in the south and the Ribblesdale multi-line siphon in the north would be replaced with a single tunnel, identified as the Proposed Marl Hill 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 shaft at the Braddup Compound (south) and reception shaft at Bonstone Compound (north). Further details on the tunnel boring and associated works are provided within Chapter 3: Design Evolution and Development Description of the ES. The location and layout of the Proposed Marl Hill Section is presented on Figure 1.

9) The ES for the Proposed Marl Hill 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 Marl Hill Section is provided in Chapter 3: Design Evolution and Development Description of the ES.

11) Subject to planning permission, the Proposed Programme of Works could start in 2023, with enabling 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 Bonstone Compound would be located at the northern end of the Proposed Scheme and would comprise a Tunnel Boring Machine (TBM) Reception Site Compound. Access to this compound would follow the existing access track from Slaidburn Road to the existing well house for approximately 350 m with a new section of temporary track then constructed across fields to the north of the existing track
  - The Braddup Compound would be located at the southern end of the Marl Hill Section and would include a drive shaft from which the tunnel would extend to the Bonstone Compound in the north. Access would be gained via the existing track that would be upgraded as part of the Proposed Programme of Works
- Surface water drainage systems serving compound sites
- Construction access tracks and associated drainage linking compounds to the public road network.

1.2.3 Construction

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

- Tunnel boring construction
  - The Proposed Marl Hill Section would be constructed using a single shield TBM
  - The new tunnel would be driven (launched) from the Braddup Compound (south end) to the Bonstone Compound (north end). The tunnel between Braddup Compound and Bonstone Compound shafts would have an internal diameter of approximately 3.0 m and would be 5.9 km in length. The maximum depth of the tunnel would be approximately 120 m below ground level
  - Arisings from tunnel construction would be brought to the surface at the Bonstone Compound and would be treated and stored temporarily before being taken off site to where they would be disposed of in Waddington Fell Quarry located approximately 2 km to the south-east
  - Temporary surface water drainage and dewatering of groundwater from deep excavations and tunnels would be stored and treated before discharge into the receiving watercourse
- 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 Marl Hill 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 wash away any debris from the construction phase. This wash water would then be attenuated in an attenuation lagoon (approximately 50 m long, 25 m wide and 2 m deep) located within the Bonstone and Braddup Compound areas. Water would then be discharged to Unnamed Watercourse 402 or Sandy Ford Brook via a de-chlorination plant at a maximum rate of 25 l/s. The commissioning process would take approximately two to three weeks.

1.2.5 Operations

15) For most of the length of the replacement aqueduct, there would be no permanent above-ground structures with most 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 be considered.

18) The existing overflow structure would however remain in operation and would link both the decommissioned aqueduct and the Proposed Marl Hill Section to Bashall Brook via an overflow weir. This overflow would protect the siphon sections of the new aqueduct from excessive pressure and provide a discharge route 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 Marl Hill Section design. This FRA only documents the findings of the main phase in support of the Proposed Marl Hill Section design as outlined in the planning application. However, a summary of the scoping process and its results is 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 Marl Hill Section would be classified as 'water transmission infrastructure' and is listed as 'Water-Compatible Development'. The construction

[3] Ministry for Housing, Communities and Local Government (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].

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 Marl Hill 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 for 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 Marl Hill Section ES. Annexe A 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 Marl Hill Section and to identify those flood sources or high-risk or high-impact elements of the Proposed Marl Hill 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:

- Conceptual designs for the construction and operation of the Proposed Marl Hill 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 Ribble Valley Strategic Flood Risk assessment[8]
- United Utilities asset data
- A web search of historical flood incidents
- The Draft Ground Investigation (GI) Factual Report (for the groundwater flood risk assessment).[9]

2.3.2 Scoping Assessment Summary

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

Table 2: Scoping phase assessment, Marl Hill Section

Flood Source / Assessment Element	Assessment Summary	Conclusion
Assessment Area The Assessment area of the Proposed Marl Hill 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 low-lying areas that define the coastline.	The Proposed Marl Hill Section is approximately 30 km from both the River Lune Estuary and the River Ribble Estuary and is at a minimum elevation of approximately 170 m above Ordnance Datum (AOD). Therefore, no risk from this source has been identified and no further assessment is necessary.	Scoped out
Fluvial Flood Risk (Main Rivers)	Environment Agency flood zone definitions are set out in the *National Planning Policy Guidance* (2014) and range	Scoped in

[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) (2020a) *Geology of Britain viewer (classic)*. [Online] Available from: https://mapapps.bgs.ac.uk/geologyofbritain/home.html. [Accessed: June 2020].
[7] BGS (2020b) BGS Groundwater Flooding Susceptibility Dataset [Accessed in 2020]
[8] Ribble Valley Borough Council (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].
[9] Geotechnics. 2020. Ground Investigation for Haweswater Aqueduct Resilience Programme – TR4 Factual Report for United Utilities Limited. Project No. PN194021.

Flood Source / Assessment Element	Assessment Summary	Conclusion
Flooding originating from Main Rivers, including the River Hodder.	from 1 to 3, with Flood Zone 1 having the lowest flood risk. The Proposed Marl Hill Section would be located entirely within Flood Zone 1. No temporary or permanent above-ground crossings of Main Rivers are proposed. No fluvial flood risk from Main Rivers to the Proposed Scheme have been identified. Construction phase discharges into the catchments of the River Hodder would 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 Ribble catchment also need to be assessed.	
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 houses 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 rates 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 Marl Hill 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 Flooding due to a significant rise in the water table, normally as a result of prolonged and heavy rainfall over a sustained period.	Earthworks associated with the construction of shafts, attenuation ponds and open-cut trenches have the potential to encounter groundwater and, in some instances, release localised artesian groundwater pressures. These works therefore have the potential to allow groundwater to flood excavation areas and reach the surface.	Scoped in

Flood Source / Assessment Element	Assessment Summary	Conclusion
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 defence structures, underground conduits, and water treatment tanks or pumping stations.	Environment Agency mapping indicates that flooding from West Bradford Reservoir would flow southwards into the River Ribble. Flooding from Stocks Reservoir would flow westwards along the River Hodder. The Proposed Marl Hill Section would be remote from the maximum extent of flooding from either reservoir. No canals, flood defences, or small reservoirs have been identified within the vicinity of the Proposed Marl Hill Section.	Scoped out
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 Marl Hill 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 Marl Hill Section and no discharges to the 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 Marl Hill Section would together 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 ▪ 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 Marl Hill Section.	Scoped out

Flood Source / Assessment Element	Assessment Summary	Conclusion
	These structures would continue to operate as they do currently and would therefore not be affected by the Proposed Marl Hill 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 tracks 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 Marl Hill 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.

37) The Proposed Marl Hill 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 Marl Hill Section including:

- Temporary construction compound sites, associated features, temporary access tracks and surface water drainage
- Management of groundwater dewatered during tunnel boring construction
- Commissioning of the tunnel by flushing water through the completed tunnel
- The 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 Marl Hill 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) 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 varied 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 Marl Hill 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 study 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 of 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 was provided
- It is assumed that in addition to embedded mitigation measures the elements of the Proposed Marl Hill 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 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

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

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

3.2 Fluvial Flood Risk

48) 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.

49) 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

50) The Proposed Marl Hill Section would be located entirely within the River Ribble catchment. The north of the section drains towards the River Hodder (Main River) whilst the south of the section drains towards Bashall Brook (Ordinary Watercourse). The Environment Agency Flood Map for Planning, as illustrated on Figure 2, shows the extents of Flood Zone 3 and 2. The *Strategic Flood Risk Assessment* for Ribble Valley[10] does not identify any areas of Functional Floodplain (Flood Zone 3b) associated with this Main River within the development envelope of the Proposed Marl Hill Section.

51) The River Hodder flows from north to south, broadly parallel to the Proposed Marl Hill Section but at a distance of approximately 3.5 km to the east of Bonstone Compound and 5.8 km to the east of Braddup Compound. All above-ground elements of the Proposed Marl Hill Section would be located entirely within Flood Zone 1.

52) Several Ordinary Watercourses are present within and adjacent to the Proposed Marl Hill Section. These Ordinary Watercourses (including Cow Hey Brook and Sandy Ford Brook) are generally small, first- or second-order streams with small catchments that are tributaries of either the River Hodder or Bashall Brook. Existing land uses are generally agricultural but include transport infrastructure such as Slaidburn Road (B6478). There are no urban or industrial areas along the route, but isolated residential and farm properties are present.

53) The Ordinary Watercourses within the planning application boundary are not included in the Environment Agency fluvial flood mapping 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 would be 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 would be typically low, the catchment characteristics, including steep topography, limited vegetation cover comprising pastoral grassland, and

[10] Ribble Valley Borough Council (2010) *op. cit.*

low permeability drift geology comprising Glacial Till,[11] are typically associated with flashy flow regimes that can rise and fall very quickly, giving little warning of flooding.

3.2.2 Fluvial Flood Risk to Enabling and Construction Activities

54) As noted in Table 2, fluvial flooding is not assessed along the route of the Proposed Marl Hill Section as this element of the scheme would be entirely below ground with no interaction with fluvial sources.

55) As shown on Figure 2, all enabling work and construction activities would be located within Flood Zone 1. Therefore, the risk of flooding from Main Rivers to these activities would be low.

56) Both construction compounds would also be located within areas with a low probability of flooding from Ordinary Watercourses as illustrated on Figure 3. However, the access roads would cross watercourses at several locations. The risk from each watercourse is detailed in Annexe A.

57) The proposed temporary access tracks linking the B6478 to the construction compounds would follow existing tracks that would be widened and resurfaced. The existing access road to the Braddup Compound would cross six Ordinary Watercourses and would therefore be at risk of fluvial flooding. 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 three of these crossing locations (Sandy Ford Brook, and Unnamed Watercourses 446 and 463) would be at risk of flooding during the 3.33 % AEP flood event, with the other three (Unnamed Watercourses 433, 431 and 430) indicated to be at risk during the 1 % AEP flood event. In both cases, flood extents are predicted be narrow with flood depths less than 300 mm.

58) The actual level of flood risk to the access tracks 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 widening of the access tracks at these locations, the existing capacity of the culverts could be altered (see Section 3.2.3), which would also influence the level of flood risk.

59) Following works to widen the existing access tracks, there would remain a residual risk of flooding to the road during flood events that exceed the capacity of the existing culverts. As the track in this location runs 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 the compound sites, measures detailed within the CCoP including the monitoring of water levels and closure of roads during periods of flooding should be implemented to help manage these residual risks and impacts upon the works.

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

3.2.3 Fluvial Flood Risk Impacts from Enabling and Construction Activities

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

- The constriction of flood flows associated with the extension of existing culverts to enable the widening of the existing access road at watercourse crossing points; or the potential for increased pass forward flow by the replacement of existing culverts with new larger capacity crossings
- Temporary increase in rates of runoff entering watercourses due to an increase in hardstanding associated with compound sites, temporary buildings and widened access tracks
- Temporary discharges of groundwater entering watercourses from excavations and tunnelling activities.

[11] BGS (2020a) *op. cit.*

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

Impact on Fluvial Flood Risk from Temporary Watercourse Crossings

63) Upgrades to existing access tracks to support vehicle movement to the Braddup Compound would require modifications to six existing culvert crossings: Sandy Ford Brook and Unnamed Watercourses 449, 430, 431, 463, 433, which are all tributaries of Bashall Brook. The probability of flooding along these watercourses is detailed in Section 3.2.2.

64) To support the widening of the existing tracks, it has not yet been determined whether the existing culvert crossings would be extended or if new culverts would be required. In both cases, any changes to the existing culvert could have flood risk impacts upstream or downstream of the crossing location. For example, a replacement culvert which is inadvertently undersized can act as a throttle and increase headwater elevation upstream, potentially leading to flooding. Conversely, a replacement culvert that is oversized may create a new problem by passing on the peak discharge which was formerly attenuated.

65) During the detailed design stage, and in accordance with CIRIA C786 [12], consideration of the potential impacts of a culvert extension or replacement on flood risk should be considered further along with other water, environment and ecology constraints.

66) To support this design process, this assessment has identified that two of the existing crossings (433 and 463,) to be extended are located within agricultural land, with no vulnerable receptors upstream or downstream of the existing crossing. The potential impact of culvert alterations on flood risk in these locations is low.

67) The existing crossings over Unnamed Watercourses 430, 431, 449 and Sandy Ford Brook are however approximately 400 m upstream of farm properties that are currently indicated to be at risk of flooding by the Risk of Flooding from Surface Water Mapping. If the existing culvert is found to be undersized, replacing the whole culvert may not be acceptable as this would increase the risk of flooding to these properties. Where appropriate, these culverts should be extended with discharge capacity retained like-for-like as a minimum to avoid increasing the risk of flooding downstream.

68) Following best practices as outlined in CIRIA C786 culverts would be sized to help maintain unchanged their flow capacity compared with those currently in place. The impact on flood risk downstream of the upgraded track would therefore be negligible and the risk to the track itself would remain unchanged.

Impact on Fluvial Flood Risk from Temporary Surface Water Discharges

69) 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).

70) In line with this strategy, the drainage system serving the Bonstone Compound would discharge surface water to Unnamed Watercourse 402 via a storage lagoon that would restrict discharge rates to a maximum of 6.2 l/s. The Braddup Compound would discharge water to Sandy Ford Brook via a storage lagoon that would restrict discharge rates to a maximum of 10 l/s.

71) Table 3 provides a summary of the discharges of surface water to watercourses. 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 3: 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
Bonstone Compound	Unnamed Watercourse 402 (tributary of Foulscales Brook)	0.53 ha	6.16 l/s	366 m^3	2.5 l/s	6.2 l/s
Braddup Compound	Sandy Ford Brook	0.97 ha	10.02 l/s	706 m^3	4 l/s	10 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

72) Groundwater would likely be intercepted 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.

73) Groundwater dewatered 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 3.

74) As shown in Table 3, the maximum rate of discharge from all tunnelling activities has been estimated by United Utilities within the drainage assessment (Annexe D) to be 6.2 l/s at the Bonstone Compound and 10 l/s at the Braddup Compound area. However, a more detailed analysis has also been undertaken as part of the groundwater impact assessment; this 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 each of the shafts at Bonstone Compound and Braddup Compound. This assessment concluded the rate of dewatering at both compounds would be less than 1 l/s. Therefore, the discharge rates from tunnelling activities assumed within the drainage strategy are conservative.

75) 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

76) 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

77) 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 generally low across the Proposed Marl Hill Section (less than 0.1 % AEP).

78) Areas of high surface water flood risk identified by the mapping are usually associated with Ordinary Watercourses as assessed in Section 3.2. There would be, however, a localised area at higher risk of surface water flooding. This is detailed in Section 3.3.2.

3.3.2 Surface Water Flood Risk to Enabling and Construction Activities

79) 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. However, areas of higher risk have been identified, which are summarised below and are detailed in Annexe A. It is noted that the Environment Agency's surface water flood mapping is a national-scale dataset that does not consider local features such as highway drainage and kerbs and walls that may influence the direction of surface water flow paths shown on Figure 3 and surface volumes and peak flows.

- An area of high surface water flood risk has been identified immediately north of the Braddup Compound. During the 3.33 % AEP rainfall event, a surface water flow path up to 300 mm deep would flow through this area into Cow Hey Brook. It is currently proposed to store topsoil stripped from the compound site in this area. Therefore, there would be a potential risk of flow being diverted resulting in flood risk increasing elsewhere, or a risk that flood flows could erode the soil stockpile
  - Given the limitations of the surface water flood mapping, the actual level of flood risk in this area may differ from that shown on the surface water flood map. Any works proposed at this location should therefore take a precautionary approach and consider the potential for large volumes of surface water flows running adjacent to and through the site
- Two other surface water flow paths would form during the 0.1 % AEP rainfall event within the vicinity of the Braddup Compound. One would extend towards Sandy Ford Brook from immediately south of the access track whilst another would run southwards approximately 20 m east of the section of open-cut trench that would connect the new tunnel to the existing aqueduct. Both flow paths would be less than 300 mm deep. The low probability of flooding and shallow flood depths would result in a low flood risk within these areas
- The access road to the Bonstone Compound would be at risk of flooding at several locations during the 0.1 % AEP rainfall event although flood depths would be less than 300 mm deep.

80) To manage surface water runoff entering compound sites and access roads, 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 upgradient and route it to an attenuation lagoon prior to discharge into watercourses. It is assumed that additional measures to manage surface water runoff through or around the soil stockpile to the north of the Braddup Compound would be developed. Therefore, the compounds are considered to have a low risk from surface water flooding.

81) 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 Unnamed Watercourse 402 and Sandy Ford Brook, along with the attenuation lagoons, 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 would be 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 is sufficient hydraulic head within the drainage system to enable effective discharge if the outfall becomes 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

82) 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.

83) 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 Table 3.

84) The proposed drainage strategies include:

- A system serving the compounds that would capture runoff and drain to attenuation lagoons prior to discharge to a receiving watercourse
- 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.

85) The proposed drainage strategy does not include specific measures to manage a surface water flow path through the proposed soil storage mound. It is assumed that at the detailed design stage, additional drainage measures would be specified that would safely route runoff through or around the soil storage area without diverting flood flows elsewhere.

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

3.4 Groundwater Flood Risk

87) 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 from groundwater. The magnitude of the change in groundwater levels relative to the ground surface and spatial extent affected is considered for the assessment of groundwater flood risk impacts.

3.4.1 Groundwater Flood Sources

88) Groundwater is stored in both superficial aquifers, typically of Glacial Till, and underlying bedrock aquifers; this is discussed in Chapter 7: Water Environment of the ES.

89) Bedrock aquifers along the Proposed Marl Hill Section comprise the Pendleside Limestone Formation, Hodderense Limestone Formation, Hodder Mudstone Formation, Clitheroe Limestone Formation, Marl Hill Shale Formation and Pendleton Formation.

90) The groundwater-bearing Glacial Till is designated as a Secondary Undifferentiated aquifer by the Environment Agency and the BGS with each bedrock formation except parts of the Marl Hill Shale Formation designated as a Secondary A aquifer. This means that each of the aquifers has the potential to store and yield limited amounts of groundwater which are potentially important to river baseflow or abstraction at a local scale only. Parts of the Marl Hill Shale Formation are designated as a Secondary Undifferentiated aquifer.

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

3.4.2 Groundwater Flood Risk to Enabling and Construction Activities

92) There are no available groundwater level data from ground investigation available for the Proposed Marl Hill Section. A conservative groundwater level of 1 m below ground level (mbgl) has been adopted for the assessment of impacts in the Proposed Marl Hill Section, which is discussed in more detail in the Water Environment section of the ES report (Chapter 7).

93) BGS susceptibility to groundwater flooding data presented on Figure 4 indicate that most of the Bonstone Compound and associated access track would have a low to very low susceptibility to groundwater flooding with smaller areas towards to northern extent of the compound having a moderate to very high susceptibility to groundwater flooding, indicating potential for flooding to property below ground level and to property at the surface respectively. It is noted that these areas are adjacent to Unnamed Watercourse 402 and are downgradient of the rest of the compound. Therefore, any emerging groundwater would enter this watercourse and not impact the compound itself to the south.

94) Most of the Braddup Compound would also have a very low to low susceptibility to groundwater flooding although a small area in the south of the compound is recorded as having a moderate to high susceptibility which is defined as areas with potential for flooding to property below ground level. The eastern extent of the access road to the Braddup Compound would be within an area with a very high susceptibility with the potential for groundwater to emerge at the surface.

95) 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.

96) In summary, based on the BGS flooding susceptibility maps, the embedded mitigation incorporated into the design of the Proposed Marl Hill 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

97) Given the proposed depths of the shaft excavations to 14 mbgl and 13.5 mbgl for the Bonstone and Braddup shafts respectively, 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 13 m and 12.5 m at the Bonstone and Braddup shafts respectively. At these depths, should any artesian pressures exist these could be released and potentially lead to upwellings of groundwater to the surface. Embedded mitigation measures specified within the CCoP such as sump drainage would be sufficient to prevent flooding from any artesian release.

98) A drainage strategy to control groundwater ingress would apply to the following shallower excavations:

- Open-cut trenches required for pipe connections to 5 mbgl
- Overflow excavations to 5 mbgl
- Attenuation ponds to 2 mbgl.

99) Dewatering techniques would temporarily lower the water table resulting in temporary, beneficial impacts on groundwater flooding within the vicinity of the excavations.

100) As shown in Annexe A, impacts from all the proposed construction works are assessed as negligible. This includes dewatering activities associated with the shafts, as the volume of water abstracted is not expected to exceed the threshold where a licence would be required.

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

3.5 Mitigation

102) Due to the low risk of flooding, mitigation embedded into the design of the enabling and construction phase activities of the Proposed Marl Hill Section is sufficient. Therefore, no additional mitigation requirements have been identified.

4. Commissioning Phase

4.1 Introduction

103) This section of the FRA focusses on both the flood risk to the Proposed Marl Hill Section and potential impacts on flood risk as a result of the Proposed Marl Hill 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

104) The exact location of the attenuation lagoons and de-chlorination plant have not been finalised, but they would be located within the planning application boundary around the Bonstone and Braddup construction compounds.

105) 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

106) The commissioning phase of the Proposed Marl Hill Section would involve the discharge of water to Unnamed Watercourse 402 in the north of the section and to Sandy Ford Brook in the South of the section. Both discharge locations are upstream of unclassified roads and farm properties. 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.

107) Prior to discharge to the local Ordinary 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 Bonstone and Braddup construction compounds. The discharge rates would be attenuated to a maximum of 25 l/s, with continuous discharge lasting for approximately four to six weeks.

108) 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 would be 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 (see Section 4.4).

4.3 Surface Water Flood Risk

4.3.1 Surface Water Flood Risk to Commissioning Activities

109) As outlined in Section 3.3, the compound locations where the raised attenuation lagoons and de-chlorination plant would be located are generally at low risk of surface water flooding (less than 0.1 % AEP), although very localised areas of high risk have been identified within the Braddup Compound. Therefore, assuming these features would be located away from the areas of high risk, the risk to commissioning activities from surface water would be low.

110) The attenuation lagoons would however be new, open, raised structures and would be a new source of potential flooding in the event that they overtopped or failed. 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) would be provided or a process developed to make available the necessary capacity once the flushing process began. 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

111) 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

112) None of the commissioning activities would require any excavations or below-ground structures that 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

113) Additional mitigation would be needed to address the potential impact on fluvial flooding from the discharge of water to the receiving watercourses.

114) 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 and determine appropriate discharge rates i.e. set the 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 put in place to restrict discharges during high water levels in the receiving watercourse.

5. Operational Phase

5.1 Introduction

115) This section of the FRA focusses on both the flood risk to the Proposed Marl Hill Section and potential impacts on flood risk as a result of the Proposed Marl Hill 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 Marl Hill Section is not predicted to have any impact on reservoir flooding and therefore this source is not considered further.

5.2 Fluvial Flood Risk

5.2.1 Fluvial Flood Risk to Operational Activities

116) 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 infrastructures at valve house building locations 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

117) 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.

118) The existing valve house buildings would be retained at each location to facilitate access to the decommissioned aqueduct. The two new valve houses located one at each end of the Proposed Marl Hill 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 is 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

119) 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

120) The proposed locations for the new valve house buildings located at each end of the Proposed Marl Hill Section are existing greenfield sites currently comprising grassland. Each of the permanent valve houses 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.

121) 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, where surface water would be discharged to the ground as a first preference.

122) 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 Marl Hill Section.

5.4 Groundwater Flood Risks

5.4.1 Groundwater Flood Risk to Operational Activities

123) All permanent infrastructure, including above-ground installations, associated with the operational activities would be located within areas with a very low susceptibility to groundwater flooding. Whilst the operational infrastructure would include below-ground elements, these would all be sealed to prevent the ingress of groundwater into the potable water supply.

124) In both valve house building 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 Marl Hill Section. Therefore, the risk of groundwater flooding to the operational activities would be low.

5.4.2 Impacts on Groundwater Flood Risk arising from Operational Activities

125) Proposed subsurface structures remaining in place during operation, including backfill, could locally disturb groundwater flows. Impermeable below-ground permanent structures have the potential to locally raise groundwater levels on the up hydraulic gradient side of the structure, and trenches backfilled with gravel materials have the potential to act as a localised drain for groundwater, locally reducing groundwater levels.

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

127) Although the backfilled open-cut trench would have a small positive effect on groundwater flooding, it would have a detrimental effect on the groundwater-dependent terrestrial ecosystem at the Bonstone Compound and for this reason Chapter 7: Water Environment of the ES has identified that clay bunds would be required. This would not alter the impact of negligible on groundwater flooding at this location.

5.5 Mitigation

128) Due to the low risk of flooding, the mitigation embedded into the design of the operational phase activities associated with the Proposed Marl Hill Section is considered sufficient. Therefore, the Proposed Marl Hill Section would be at low risk of 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

129) 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 Marl Hill Section and the ongoing discharge of groundwater ingress into the Bashall Brook. This section focusses only on fluvial flood risk impacts as no other flood sources would be affected.

6.2 Fluvial Flood Risk

6.2.1 Impact on Fluvial Flood Risk from Decommissioning Activities

130) As part of the Proposed Marl Hill 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 Bashall Brook via the existing overflow structure.

131) 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 Table 4. Future uncertainties have limited the ability to provide a realistic forecast beyond 2055. United Utilities would continue to monitor the tunnel condition.

132) To assess the potential impact of these groundwater discharges from the decommissioned Haweswater Aqueduct into the Bashall Brook, a comparison has been made with QMED[14] and Q10[15] predicted flow rates at the discharge location within the Bashall Brook, as presented in Table 4.

Table 4: Comparison of groundwater discharge and peak flows within Bashall Brook

Bashall Brook Peak Flow		Groundwater Discharge Estimate for 2055		Percentage Increase in Peak Flow	
		Mean	Maximum	Mean	Maximum
Q10	0.35 m^3/s	0.015 m^3/s	0.032 m^3/s	+4.37 %	+8.62 %
QMED	6.37 m^3/s	0.015 m^3/s	0.032 m^3/s	+0.24 %	+0.47 %

133) Table 4 shows that even the maximum estimated discharge from the decommissioned aqueduct would be a negligible contribution to the QMED flow in Bashall Brook (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.

134) 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 Marl Hill Section is also considered to be negligible.

6.3 Groundwater Flood Risks

6.3.1 Impacts on Groundwater Flood Risk Arising from Decommissioning Activities

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

[14] 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.
[15] Q10 is the 90-percentile flow or the flow equalled or exceeded for 10 % of the flow record.

136) 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 as shown in Annexe A.

6.4 Mitigation

137) Due to the negligible impacts on flooding associated with the decommissioning of the existing aqueduct, no additional mitigation requirements have been identified.

7. Summary and Conclusion

7.1 Summary

138) This FRA has been prepared to support the planning application for the Proposed Marl Hill Section of the Haweswater Aqueduct Resilience Programme, which would be located at the central section of the aqueduct. This extends from approximately 1.3 km south of Newton-in-Bowland to 1.3 km north of Waddington.

139) 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 Marl Hill Section design development through the EIA process and informs Chapter 8: Flood Risk of the ES.

140) The Proposed Marl Hill Section would be classified as 'water transmission infrastructure' and is therefore considered within the NPPF to be a 'water-compatible development' that would be 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.

141) 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 and groundwater flooding.

142) For most of the length of the replacement aqueduct, there would be no permanent above-ground structures with most of the new sections 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 Marl Hill 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
- 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.

143) Using readily available national flood risk datasets, the FRA concludes that the level of flood risk to the Proposed Marl Hill Section would be low from all sources of flooding. 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.

144) The main impacts on flood risk are associated with commissioning phase discharges. Further assessment would be required to confirm that these could be managed without increasing the risk of flooding to receptors downstream. Pending the detailed assessment, these are assumed to have a moderate impact.

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

146) Table 5 provides a summary of flood risk assessment.

Table 5: Flood risk assessment summary

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

147) A key assumption of this assessment is that in addition to embedded mitigation measures, the elements of the Proposed Marl Hill 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

148) As identified in Section 1.2, the Proposed Marl Hill 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.

149) Discharges into the Hodder catchment from the northern part of the Proposed Marl Hill Section would be limited to construction phase discharges from the Bonstone 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 Hodder catchment would result in a negligible impact on runoff rates within the receiving watercourses.

150) The River Ribble catchment would also receive construction phase discharges from the Proposed Bowland Section and the Proposed Haslingden and Walmersley Section of the Haweswater Aqueduct Resilience Programme. Operational discharges of groundwater from the Proposed Bowland 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.

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

7.3 Conclusion

152) In conclusion, based on the assumption that embedded mitigation would be effectively designed and implemented, good practice applied, and further assessment and mitigation would be undertaken to make sure that commissioning phase discharges to watercourses would be managed effectively, the Proposed Marl Hill Section has been assessed as having 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 Marl Hill Section

Environmental Statement

Volume 4

Appendix 8.1: Flood Risk Assessment

Annexe A Flood Risk Assessment Tables

June 2021

Water for the North West

Haweswater Aqueduct Resilience Programme – Proposed Marl Hill Section

Project No:	B27070CT
Document Title:	Proposed Marl Hill Section Environmental Statement Volume 4 Appendix 8.1: Flood Risk Assessment Annexe A Flood Risk Assessment Tables
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Flood Risk Assessment Tables

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1. Fluvial flood risk – Enabling and Construction Phase Marl Hill Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Unnamed Watercourse 388	Ordinary Watercourse tributary of Foulscales Brook (Ordinary Watercourse). Foulscales Brook is a tributary of the River Hodder (Main River), which is approximately 765 m north from the Bonstone TBM Reception Site Compound area.	Bonstone TBM Reception Site Compound area would be approximately 250 m south of Unnamed Watercourse 388.	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Within the red line boundary area of the Proposed Scheme the probability of flooding is lower than or equal to 1 % AEP. Land use along this watercourse is agricultural.		The proposed Bonstone TBM Reception Site Compound is at low risk of fluvial flooding from this watercourse. Therefore, the main fluvial flood risk impact would be from changes in surface water runoff. 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 watercourse 388. Surface water runoff from the proposed TBM Reception Site Compound would however be captured and attenuated within a storage lagoon prior to discharge into watercourse 402 (a tributary of watercourse 388) at greenfield rates (6.2 l/s). The attenuation of runoff and discharge to watercourse 402 would ensure that there would be a negligible change in peak flows in watercourse 388 and that increases in fluvial flood risk to downstream receptors would be **negligible**.	Neutral

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Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Unnamed Watercourse 1353	Ordinary Watercourse Tributary of Unnamed Watercourse 388	A new section of access road would extend from the existing track to the construction compound across fields to the north west. This section of new access road would be approximately 450 m long and would be approximately 200 m to the south (upgradient) of watercourse 1353.	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Surface water flooding is predicted upstream of the head of watercourse 1353. This is not considered to be fluvial flooding and is assessed within the surface water section. Land use along this watercourse is agricultural.		The new section of the access road would be at low risk of fluvial flooding and no watercourses would be crossed. Therefore, the main impact would be associated with changes to runoff rates into watercourses. Construction of the new, temporary access road would increase the area of impermeable surfaces within the catchment of Unnamed Watercourse 1353, 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 embedded mitigation would be implemented including the use of roadside drainage that would attenuate any increase in runoff rate and ensure that the impact on flood risk from any changes to surface water runoff rates would be **negligible**.	Neutral
Unnamed Watercourse 402	Ordinary Watercourse Tributary of Unnamed Watercourse 388	The Bonstone TBM Reception Site Compound would be approximately 75 m south of Unnamed Watercourse 402. Surface water runoff from the proposed compound would be discharged into the	**Low**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is less than or equal to 1 % AEP.		The proposed Bonstone TBM Reception Site Compound is at low risk of fluvial flooding from this watercourse. Therefore, the main fluvial flood risk impact would be from changes in surface water runoff and discharges of groundwater from excavations increasing flow within the watercourse. Construction compound sites have the potential to increase surface water runoff due to an increase in impermeable surfaces. Increased runoff rates into the watercourse would have the potential to increase fluvial flood risk within watercourse 402. Surface water runoff from the proposed TBM Reception Site Compound would however be captured and attenuated within a storage lagoon prior to discharge into watercourse 402 at greenfield runoff rates (6.2 l/s). The	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		head of this watercourse.		Land use along this watercourse is agricultural.		attenuation of runoff would ensure that there would be a negligible change in peak flows in this watercourse 402 and that increases in fluvial flood risk to downstream receptors would be **negligible**.	
						Excavations in this area include the TBM reception shaft and an open cut trench to connect the new tunnel to the existing aqueduct. Groundwater from these excavations would be discharged towards Unnamed Watercourse 402 via the storage lagoon and treatment plant used to manage surface water runoff. Groundwater flows are predicted to be less than 0.5 l/s and the management of these flows through the storage lagoon prior to discharge to ground would ensure that the impact on fluvial flood risk downstream of the discharge location to watercourse 402 would be **negligible**.	Neutral
Unnamed Watercourse 1365 Ordinary Watercourse Tributary of Unnamed Watercourse 403 and Bonstone Brook		The access road to the Bonstone TBM reception compound would be approximately 130 m to the north of Unnamed Watercourse 1365. The access road in this location would comprise of approximately 320 m of upgraded farm track from Slaidburn Road (B6478).	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Within the red line boundary of the Proposed Scheme the probability of flooding from this watercourse is less than or equal to 1 % AEP. Land use along this watercourse is agricultural.		The upgraded and new sections of the access road would be at low risk of fluvial flooding and no watercourses would be crossed. Therefore, the main impact would be associated with changes to runoff rates into watercourses. Upgrades to the existing track including widening and resurfacing would have the potential to increase runoff rates into this watercourse due to an increase in impermeable surfaces. However, whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that embedded mitigation would be implemented including the use of roadside drainage that would attenuate any increase in runoff rate and ensure that the impact on fluvial flood risk to watercourse 1365 from any changes to surface water runoff rates would be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Cow Hey Brook	Ordinary Watercourse Tributary of Bashall Brook (Ordinary Watercourse)	Braddup TBM Drive Site Compound area would be approximately 110 m east of Cow Hey Brook.	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural.		The proposed Braddup TBM Drive Site Compound is at low risk of fluvial flooding from this watercourse. Therefore, the main impact would be from changes in surface water runoff (due to an increase in impermeable surfaces) and discharges of groundwater from excavations increasing flow within the watercourse. Surface water runoff from the proposed TBM Drive Site Compound would however be captured and attenuated within a storage lagoon prior to discharge into Sandy Ford Brook (a tributary of Cow Hey Brook) at greenfield runoff rate (10 l/s). The discharge of runoff from the compound to Sandy Ford Brook, would ensure that the change in peak flows in Cow Hey Brook would be **negligible**.	Neutral
						Excavations in this area include the TBM drive shaft and an open cut trench. Groundwater from these excavations would also be discharged into Sandy Ford Brook via the storage lagoon used to manage surface water runoff. Groundwater flows are predicted to be less than 0.5 l/s and the management of these flows through the storage lagoon would ensure that the impact on fluvial flood risk downstream of the discharge location to Cow Hey Brook would be **negligible**.	Neutral
Unnamed Watercourse 444	Ordinary Watercourse Tributary of Bashall Brook (Ordinary Watercourse)	The open cut trench linking the TBM drive shaft to the existing aqueduct would be approximately 30 m north east of Unnamed Watercourse 444.	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural.		The proposed open cut trench within Braddup TBM Drive Site Compound is at low risk of fluvial flooding from this watercourse. Therefore, the main impact would be from discharges of groundwater from the excavation increasing flow within the watercourse. Excavations in this area include the TBM drive shaft and an open cut trench. Groundwater from these excavations would be discharged into Sandy Ford Brook (a tributary of Cow Hey Brook and Bashall Brook) via the storage lagoon used to manage surface water runoff. No groundwater would be discharged to Unnamed Watercourse 444, therefore the magnitude of the effects of dewatering activities on flood risk in this watercourse would be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Sandy Ford Brook	Ordinary Watercourse Tributary of Bashall Brook (Ordinary Watercourse)	Braddup TBM Drive Site Compound area would be approximately 60 m west of Sandy Ford Brook, which runs parallel with the proposed compound area. Surface water runoff from the proposed compound would be discharged into this watercourse. The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup TBM Drive Site Compound area would cross 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 along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural with farm buildings located downstream.		The proposed Braddup TBM Drive Site Compound is at low risk of fluvial flooding from this watercourse. Therefore, the main 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. However, surface water runoff from the proposed TBM Drive Site Compound would be captured and attenuated within a storage lagoon prior to discharge into Sandy Ford Brook at greenfield rates (10 l/s). The attenuation of runoff would ensure that the change in peak flows in Sandy Ford Brook would be **negligible**.	Neutral
						The existing, permanent access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. This access road would be at low risk of fluvial flooding except for where it crosses watercourses including Sandy Ford Brook and its narrow floodplain. Outline designs for the proposed crossing are not currently available. An extended culvert to accommodate the additional width of the track has the potential to constrict flood flows if inadvertently undersized increasing flood risk upstream. Conversely, a new larger replacement culvert would have the potential to increase pass forward flow, increasing fluvial flood risk downstream to Cross Lane and Braddup House. Flood risk would be considered during the detailed design of a new or extended culvert in accordance with CIRIA C786. On flood risk grounds, it is recommended that the discharge capacity would be retained like-for-like to avoid increasing risk to downstream properties. Therefore, the impacts on flood risk upstream and downstream would be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
						Excavations in this area include the TBM drive shaft and the open cut trench lining the drive shaft to the existing aqueduct. Groundwater from these excavations would be discharged into Sandy Ford Brook via the storage lagoon used to manage surface water runoff. Groundwater flows are predicted to be less than 0.5 l/s and the management 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 449, which continue as 446 (Ordinary Watercourse) Tributary of Bashall Brook (Ordinary Watercourse)		The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup TBM Drive Site Compound area would be approximately 20 m south of Unnamed Watercourse 449 and approximately 105 m north of Unnamed Watercourse 446.	**High** Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural with a residential property downstream.			The existing access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. This access road would be at low risk of fluvial flooding except for where it crosses watercourses including Unnamed Watercourse 449 and its narrow floodplain. Outline designs for the proposed crossing are not currently available. An extended culvert to accommodate the additional width of the track has the potential to constrict flood flows if inadvertently undersized increasing flood risk upstream. Conversely, a new larger replacement culvert would have the potential to increase pass forward flow, increasing fluvial flood risk downstream. Flood risk would be considered during the detailed design of a new or extended culvert in accordance with CIRIA C786. On flood risk grounds, it is recommended that the discharge capacity would be retained like-for-like to avoid increasing risk to downstream receptors including Cross Lane and Braddup House. Therefore, the impacts on flood risk upstream and downstream would be **negligible**.	Neutral
Unnamed Watercourse 437 Ordinary Watercourse		The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup TBM Drive Site	**High** Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates			The existing access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. The road would be at low risk of fluvial flooding from this watercourse and does not cross it.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Tributary of Bashall Brook (Ordinary Watercourse)		Compound area would be approximately 73 m north of Unnamed Watercourse 437.		that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural.		Therefore, the main impact would be potential increases in surface water runoff rate into the catchment of Unnamed Watercourse 437. However, whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that embedded mitigation would be implemented including the use of roadside drainage that would attenuate any increase in runoff rate and ensure that the impact on fluvial flood risk to watercourse 437 from any changes to surface water runoff rates would be **negligible**.	
Unnamed Watercourse 430	Ordinary Watercourse Tributary of Bashall Brook (Ordinary Watercourse)	The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup TBM Drive Site Compound area would cross Unnamed Watercourse 430 via an existing culvert.	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural with a residential property downstream.		The existing access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. This access road would be at low risk of fluvial flooding except for where it crosses this watercourse and its narrow floodplain. It is assumed that the existing culvert would be upgraded. Outline designs for the proposed crossing are not currently available. An extended culvert to accommodate the additional width of the track has the potential to constrict flood flows if inadvertently undersized increasing flood risk upstream. Conversely, a new larger replacement culvert would have the potential to increase pass forward flow, increasing fluvial flood risk downstream. Flood risk would be considered during the detailed design of a new or extended culvert in accordance with CIRIA C786. On flood risk grounds, it is recommended that the discharge capacity would be retained like-for-like to avoid increasing risk to downstream receptors including Cross Lane and Colthurst Hall. Therefore, the impacts on flood risk upstream and downstream would be **negligible**.	Neutral
Unnamed Watercourse 431	Ordinary Watercourse	The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for		The existing access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. This access	Neutral

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Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Tributary of Bashall Brook (Ordinary Watercourse)		TBM Drive Site Compound area would cross Unnamed Watercourse 431 via an existing culvert.		Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural with residential properties downstream.		road would be at low risk of fluvial flooding except for where it crosses this watercourse and its narrow floodplain. Outline designs for the proposed crossing are not currently available. An extended culvert to accommodate the additional width of the track has the potential to constrict flood flows if inadvertently undersized increasing flood risk upstream. Conversely, a new larger replacement culvert would have the potential to increase pass forward flow, increasing fluvial flood risk downstream. Flood risk would be considered during the detailed design of a new or extended culvert in accordance with CIRIA C786. On flood risk grounds, it is recommended that the discharge capacity would be retained like-for-like to avoid increasing risk to downstream receptors including Cross Lane and Colthurst Bungalows. Therefore, the impacts on flood risk upstream and downstream would be **negligible**.	
Unnamed Watercourse 463 (Ordinary Watercourse) Tributary of Bashall Brook (Ordinary Watercourse)		The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup TBM Drive Site Compound area would cross Unnamed Watercourse 463 via an existing culvert.	**High**	Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural.		The existing access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. This access road would be at low risk of fluvial flooding except for where it crosses this watercourse and its narrow floodplain. It is assumed that the existing culvert would be upgraded. Outline designs for the proposed crossing are not currently available. An extended culvert to accommodate the additional width of the track has the potential to constrict flood flows if inadvertently undersized increasing flood risk upstream. Flood risk would be considered during the detailed design of a new or extended culvert in accordance with CIRIA C786. On flood risk grounds, it is recommended that the discharge capacity would be retained like-for-like to avoid increasing risk to downstream. Therefore, the impacts on flood risk upstream and downstream would be **negligible**.	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Unnamed Watercourse 433 (Ordinary watercourse) Tributary of Bashall Brook (Ordinary Watercourse)		The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup TBM Drive Site Compound area would cross Unnamed Watercourse 433 via an existing culvert.	**High** Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural.		The existing access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. This access road would be at low risk of fluvial flooding except for where it crosses this watercourse and its narrow floodplain. It is assumed that the existing culvert would be upgraded. Outline designs for the proposed crossing are not currently available. An extended culvert to accommodate the additional width of the track has the potential to constrict flood flows if inadvertently undersized increasing flood risk upstream. Flood risk would be considered during the detailed design of a new or extended culvert in accordance with CIRIA C786. On flood risk grounds, it is recommended that the discharge capacity would be retained like-for-like to avoid increasing risk to downstream. Therefore, the impacts on flood risk upstream and downstream would be **negligible**.		Neutral
Unnamed Watercourse 436 (Ordinary watercourse) Tributary of Waddington Brook (Ordinary Watercourse)		The upgraded permanent site access road from Slaidburn Road (B6478) to Braddup TBM Drive Site Compound area would be approximately 30 m west of Unnamed Watercourse 436.	**Very High** Flood Zone 1. Fluvial flood risk is inferred from the Flood Map for Surface Water and indicates that the probability of flooding along this watercourse is greater than or equal to 3.33 % AEP. Receptors at risk include the B6478 and residential property.		The existing access track between Slaidburn Road and Braddup TBM Drive Site Compound would be upgraded by widening it to a width of 7.7 m and installing a tarmac surface to replace the existing concrete surface. The road would be at low risk of fluvial flooding from this watercourse and does not cross it. Therefore, the main impact would be potential increases in surface water runoff rate into the catchment of Unnamed Watercourse 436. However, whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that embedded mitigation would be implemented including the use of roadside drainage that would attenuate any increase in runoff rate and ensure that the impact on fluvial flood risk to Unnamed Watercourse 436 from any changes to surface water runoff rates would be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
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. Surface water flood risk – Enabling and Construction 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 – Bonstone TBM Reception Site Compound area		The Bonstone Compound area and new and upgraded sections of existing access road from Slaidburn Road (B6478).	**Low** The Flood Map for Surface Water indicates that surface water flood risk across the Bonstone Compound and associated temporary access road is generally low (less than 0.1 % AEP). However, during the 0.1 % AEP rainfall event, three areas of surface water flooding		According to the Flood Map for Surface Water, the proposed Bonstone TBM Reception Site compound area is at low risk of surface water flooding. Due to an increase in impermeable surfaces, the Proposed Scheme has the potential to increase surface water runoff and therefore increasing the risk of flooding downstream through the surface water catchment. Surface water runoff from the proposed TBM Reception Site Compound would however be captured and attenuated within a storage lagoon prior to discharge into watercourse 402 at greenfield rates (6.2 l/s). The attenuation of runoff and discharge to watercourse (rather than ground) would ensure that the impact through the surface water catchment to downstream receptors would be **negligible.**		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
				would occur that would be less than 300 mm deep. One would extend from the north of the TBM reception compound towards Unnamed Watercourse 402. Another flow path would cross the proposed new section of access road and flow towards Unnamed Watercourse 1353 whilst the third would form along the existing track that would be upgraded. The current land use in the area is agricultural.	Whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that embedded mitigation would be implemented including the use of roadside drainage that would attenuate any increase in runoff rate and ensure that the impact on surface water flooding from any changes to surface water runoff rates would be **negligible**.		Neutral
Surface water flooding – Braddup TBM Drive Site Compound area		The Braddup Compound area and the upgraded access road from Slaidburn Road (B6478).	**High** The Flood Map for Surface Water indicates that the probability of surface water flooding is generally low (less than 0.1 % AEP). However, during the 3.33 % AEP rainfall event, a surface		According to the Flood Map for Surface Water, the proposed soil storage area within the north of the Braddup TBM Drive Site Compound is at high risk of surface water flooding. Whilst the current drainage designs do not show any perimeter drainage in this area, it is assumed that at the detailed design stage, additional drainage would be included that would route runoff around the soil storage area. Further drainage measures would also be considered in the vicinity of the open cut trench. These drainage measures would maintain existing catchments and ensure that the impact on downstream receptors would be **negligible**.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
				water flow path less than 300 mm deep would flow through the north of the red line boundary area (currently proposed for the storage of soil form the strip of the compound site) towards Cow Hey Brook. Two other surface water flow paths would form during the 0.1 % AEP rainfall event. One would extend towards Sandy Ford Brook from immediately south of the access track whilst another would run southwards approximately 20 m east of the section of open cut that would connect the new tunnel to the existing aqueduct. Both flow paths would be less than 300 mm deep. The current land use in the area is agricultural.		Due to an increase in impermeable surfaces, the proposed construction compound has the potential to increase surface water runoff, increasing the risk of flooding downstream through the surface water catchment. Surface water runoff from the proposed TBM Drive Site Compound would be captured, attenuated and discharged to Sandy Ford Brook at greenfield runoff rate (10 l/s). The attenuation of runoff would ensure that there would be a negligible change to surface water runoff rates and that the impact on downstream receptors would be **negligible.**	Neutral
						Whilst the surface water drainage strategy for the access road has not yet been finalised, it is assumed that embedded mitigation would be implemented including the use of roadside drainage that would attenuate any increase in runoff rate and ensure that the impact on surface water flooding from any changes to surface water runoff rates would be **negligible**.	Neutral

3. Groundwater flood risk – Enabling and Construction Phase Marl Hill Section

<table>
<tr><th colspan="2">Flood Source</th><th rowspan="2">Proposed Scheme Element</th><th colspan="2">Likelihood / Importance</th><th colspan="2">Magnitude of Change</th><th>Significance</th></tr>
<tr><th>Name</th><th>Type</th><th>Score</th><th>Justification</th><th>Score</th><th>Justification</th><th>Score</th></tr>
<tr><td rowspan="3">Secondary Undifferentiated superficial aquifer (Till)</td><td rowspan="3"></td><td>Bonstone Shaft</td><td colspan="2">Low
There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity).
Land use: rough grazing farmland (low sensitivity).
The most conservative sensitivity for this element is low.</td><td colspan="2">Although there is no available GI data to indicate the groundwater level, a conservative groundwater level of 1 mbgl has been assumed. Given the proposed depths of the shaft excavation to 14 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 13 m.
At these depths, artesian pressures may be encountered which could potentially lead to upwellings of groundwater at the surface. Specified embedded mitigation measures such as sump drainage is expected to adequately cope with artesian release.
The magnitude of change to groundwater flood risk would therefore be negligible.</td><td>Neutral</td></tr>
<tr><td>Bonstone Attenuation Pond</td><td colspan="2">Low
There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity).
Land uses: rough grazing farmland (low sensitivity).
The most conservative sensitivity for this element is low.</td><td colspan="2">Given the proposed depths of the excavation to 2 mbgl and in the absence of actual groundwater level data an assumed groundwater level of 1 mbgl at this location, no significant amount of groundwater would be expected to drain into the open excavation during construction from the Till. Any dewatering that was required would have a marginal beneficial effect on groundwater flood risk.
The magnitude of change to groundwater flood risk would therefore be negligible.</td><td>Neutral</td></tr>
<tr><td>Bonstone Access Track / Haul Road</td><td colspan="2">High
There is a Very Low to Low potential risk of groundwater emergence</td><td colspan="2">No changes to groundwater levels would be anticipated as no dewatering would be required and any change to recharge would be negligible.</td><td>Neutral</td></tr>
</table>

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). Land uses: rough grazing farmland (low sensitivity); farm access track (medium sensitivity); farm buildings (high sensitivity); Slaidburn Road B6478 (high sensitivity). The most conservative sensitivity for this element is high.		The magnitude of change to groundwater flood risk would therefore be **negligible.**		
		Bonstone Connection – open-cut section connecting the existing pipeline to the Proposed Marl Hill Tunnel	**High** There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity); farm access track (medium sensitivity); existing valve house / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		Although the BGS flood susceptibility data does not indicate shallow groundwater conditions, given the proposed depth of the excavation to 5mbgl, groundwater may be encountered. 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. Any dewatering would have a beneficial effect on groundwater flood risk. The magnitude of change to groundwater flood risk would therefore be **negligible.**		Neutral
		Bonstone Compound Working Platform Area	**High** For the most part, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low		No changes to groundwater levels would be anticipated due to the shallow nature of the works and no dewatering would be require for the 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
			sensitivity). Exceptions lie in the north of the proposed compound area where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity) with a small area in the northwesternmost extent classified as Very High (potential for groundwater flooding to occur at the surface). Land uses: rough grazing farmland (low sensitivity); farm access track (medium sensitivity); existing valve houses / infrastructure (high sensitivity); farm buildings (high sensitivity). The most conservative sensitivity for this element is high.				
		Braddup Shaft	**Low** There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity).		Although there is no available GI data to indicate the groundwater level, a conservative groundwater level of 1 mbgl has been assumed. Given the proposed depths of the shaft excavation to 13.5 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 12.5 m. At these depths, artesian pressures may be encountered which could potentially lead to upwellings of groundwater at the surface. Specified		Neutral

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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 low.		embedded mitigation measures such as sump drainage is expected to adequately cope with artesian release. The magnitude of change to groundwater flood risk would therefore be **negligible.**		
		Braddup Attenuation Pond	**Low** There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.		Given the proposed depths of the excavation to 2 mbgl and in the absence of actual groundwater level data an assumed groundwater level of 1mbgl at this location, no significant amount of groundwater would be expected to drain into the open excavation during construction from the Till. Any dewatering that was required 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
		Braddup Access Track / Haul Road	**High**	In the western extent of the proposed access road, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). In the central area of the proposed access road the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties) (medium sensitivity). In the eastern extent of the proposed access road, the susceptibility of groundwater flooding is Very High (potential for groundwater flooding to occur at the surface) (high sensitivity). Land uses: farm access track (medium sensitivity); rough grazing farmland (low sensitivity); Slaidburn Road B6478 (high 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
Secondary A Bedrock Aquifer (Clitheroe Limestone Formation and Hodder		Braddup Connection – open-cut section connecting the existing pipeline	**High**	For the most part, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding		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,	Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Mudstone Formation (Undifferentiated))		with the Proposed Marl Hill Tunnel	to occur) (BGS, 2020) (low sensitivity). Exception lies in the south of the open-cut section where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties). Land uses: farm access track (medium sensitivity); rough grazing farmland (low sensitivity); existing valve house / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		lowering the water table potentially by 4m (assuming a groundwater level of 1 mbgl). Any dewatering would have a beneficial effect on groundwater flood risk. The magnitude of change to groundwater flood risk would therefore be **negligible.**		
		Ribblesdale North Well Overflow (Overflow at Braddup)	**High** There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: farm access track (medium sensitivity); rough grazing farmland (low sensitivity); existing valve house / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		Given the proposed depths of the excavation to 5mbgl, 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 4m (assuming a groundwater level of 1mbgl). Any dewatering would have a 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
		Braddup Compound area enabling works (e.g. topsoil stripping)	**High** For the most part, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Exceptions lie in the southern areas of the proposed compound (excluding the southwest corner) where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties). Land uses: rough grazing farmland (low sensitivity); farm access track (medium sensitivity); existing valve houses / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		No changes to groundwater levels would be anticipated due to the shallow nature of the works and no dewatering would be required for the construction of the compound. The magnitude of change to groundwater flood risk would therefore be **negligible.**		Neutral
Pendleton Formation (Secondary A bedrock aquifer)		Braddup Connection – open-cut section connecting the existing pipeline with the proposed Marl Hill Tunnel	**High** For the most part, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Exception lies in the south of the open-cut section where the susceptibility of groundwater		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 4 m (assuming a groundwater level of 1 mbgl). Any dewatering would have a beneficial effect on groundwater flood risk.		Neutral

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			flooding is classified as Moderate to High (potential for flooding of below ground properties). Land uses: farm access track (medium sensitivity); rough grazing farmland (low sensitivity); existing valve house / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		The magnitude of change to groundwater flood risk would therefore be **negligible.**		
		Braddup Compound area enabling works (e.g. topsoil stripping)	**High** For the most part, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Exceptions lie in the southern areas of the proposed compound (excluding the southwest corner) where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties). Land uses: rough grazing farmland (low sensitivity); farm access track (medium sensitivity); existing valve houses / infrastructure (high sensitivity).		No changes to groundwater levels would be anticipated due to the shallow nature of the works and no dewatering would be required for the 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
				The most conservative sensitivity for this element is high.			

4. Fluvial 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
Unnamed Watercourse 402 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 Bonstone Construction Compound approximately 75 m south of Unnamed Watercourse 402. An outfall pipe would discharge to Unnamed Watercourse 402.	**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 and flows through agricultural land.		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. 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.	Slight

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Sandy Ford Brook	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 Braddup Construction Compound approximately 60 m west of Sandy Ford Brook. An outfall pipe would discharge 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 along this watercourse is greater than or equal to 3.33 % AEP. Land use along this watercourse is agricultural with farm buildings located downstream.		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. 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

5. Surface water 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 – Bonstone TBM Reception Site Compound area		The Bonstone Compound area and new and upgraded sections of existing access road from Slaidburn Road (B6478). Temporary lagoons with the associated dechlorinating plants and connecting pipework.	**Low** The Flood Map for Surface Water indicates that surface water flood risk across the Bonstone Compound and associated temporary access road is generally low (less than 0.1 % AEP). However, during the 0.1 % AEP rainfall event, three areas of surface water flooding would occur that would be less than 300 mm deep. One would extend from the north of the TBM reception compound towards Unnamed Watercourse 402. Another flow path would cross the proposed new section of access road and flow towards Unnamed Watercourse 1353, whilst the third would form along the existing track that would be upgraded. The current land use in the area is agricultural.		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. 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. 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

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Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Surface water flooding – Braddup TBM Drive Site Compound area		The Braddup Compound area and the upgraded access road from Slaidburn Road (B6478). Temporary lagoons with the associated dechlorinating plants and connecting pipework.	**High**	The Flood Map for Surface Water indicates that the probability of surface water flooding is generally low (less than 0.1 % AEP). However, during the 3.33 % AEP rainfall event, a surface water flow path less than 300 mm deep would flow through the north of the red line boundary area (currently proposed for the storage of soil form the strip of the compound site) towards Cow Hey Brook. Two other surface water flow paths would form during the 0.1 % AEP rainfall event. One would extend towards Sandy Ford Brook from immediately south of the access track whilst another would run southwards approximately 20 m east of the section of open cut that would connect the new tunnel to the existing aqueduct. Both flow paths would be less than 300 mm deep.		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. 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. 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
				The current land use in the area is agricultural.			

6. Groundwater 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
					No impacts identified		

7. Fluvial flood risk – Operational Phase Marl Hill Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Unnamed Watercourse 402 Ordinary Watercourse		A new permanent valve house building, which would be approximately 70 m south-east of this watercourse.	**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 and flows through agricultural land.		The proposed valve house building is located in Flood Zone 1 and is at low risk of fluvial flooding from this watercourse. Therefore, the main potential impact would be from changes in surface water runoff increasing flow within the watercourse. The development of new permanent above ground infrastructure, including a new valve house and associated areas of hardstanding has the potential to increase surface water runoff rates, which could increase the risk of fluvial flooding associated with Unnamed Watercourse 402 to downstream receptors. No designs are available for the proposed valve house. However, it is assumed that a drainage strategy would be developed during detailed design and that runoff 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
Cow Hey Brook	Ordinary Watercourse	A new permanent valve house building would be approximately 110 m east of this watercourse.	**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 and flows through agricultural land.		The proposed valve house building is located in Flood Zone 1 and is at low risk of fluvial flooding from this watercourse. Therefore, the main potential impact would be from changes in surface water runoff increasing flow within the watercourse. The development of new permanent above ground infrastructure, including a new valve house and associated areas of hardstanding has the potential to increase surface water runoff rates, which could increase the risk of fluvial flooding associated with Cow Hey Brook to downstream receptors. No designs are available for the proposed valve house. However, it is assumed that a drainage strategy would be developed during detailed design and that runoff 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

8. Surface water flood risk – Operational Phase Marl Hill Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Surface water flow path outside of Bonstone TBM Reception Site Compound area		A permanent valve house building would be around 115 m north of the surface water flowpath towards Unnamed Watercourse 402.	**Low**	The Flood Map for Surface Water indicates that flood risk in the vicinity of the proposed valve house is generally low (less than 0.1 % AEP). The current land use in the area is agricultural.		The proposed valve house building in this area has a low risk of surface water flooding. The permanent access road has a medium risk of surface water flooding on the unnamed road before the field access. No drainage designs are available for the proposed valve house and permanent access road. However, it is assumed that a surface water drainage strategy would be developed during detailed design and that runoff would be captured and attenuated using sustainable drainage techniques and either discharge to ground or the watercourse at greenfield runoff rates or. 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
		The permanent access road using existing farmers track from unnamed road through field.					
Surface water flow path within west Braddup TBM Drive Site Compound area		A permanent valve house building would be approximately 50 m east of the existing valve house. The permanent access road using existing access track.	**Low**	The Flood Map for Surface Water indicates that flood risk in the vicinity of the proposed valve house is generally low. However, during the 0.1 % AEP flood event, a surface water flow path less than 300 mm deep would flow across the access road. The land use in the area is agricultural.		The proposed valve house building and its existing permanent access track in this area has a low risk of surface water flooding. No designs are available for the proposed valve house or the upgraded access road. However, it is assumed that a surface water drainage strategy would be developed during detailed design and that runoff would be captured and attenuated using sustainable drainage techniques and either discharge to ground or the watercourse at greenfield runoff rates. Therefore, the impact on surface water flood risk would be **negligible**.	Neutral

9. Groundwater flood risk – Operational Phase Marl Hill Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Secondary Undifferentiated Superficial Aquifer (Till) Groundwater flooding		Bonstone Shaft	**Low**	There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity).		The proposed shaft, 15 m in diameter and 14 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

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 low.				
		Reinstated Bonstone Attenuation Pond	**Low**	No significant risk of groundwater emergence has been identified by the BGS (2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.	The attenuation ponds are 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
		Bonstone Permanent Access Track	**High**	There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity); farm access track (medium sensitivity); farm buildings (high sensitivity); Slaidburn Road B6478 (high 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

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Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
		Bonstone Connection – open cut section connecting the existing pipeline to the Proposed Marl Hill Tunnel	**High** There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity); farm access track (medium sensitivity); existing valve house / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		The open-cut construction method proposed for the Bonstone 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
		Braddup Shaft	**Low** There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.		The proposed shaft, 15 m in diameter and 13.5 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 Braddup Attenuation Pond	**Low** There is a Very Low to Low potential risk of groundwater emergence (limited potential for		The attenuation ponds are 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		Neutral

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Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
			groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: rough grazing farmland (low sensitivity). The most conservative sensitivity for this element is low.		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.**		
		Ribblesdale North Well Overflow (Overflow at Braddup)	**High** There is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Land uses: farm access track (medium sensitivity); rough grazing farmland (low sensitivity); existing valve house / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		The open-cut construction method proposed for the Braddup 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
Secondary A Bedrock Aquifer (Clitheroe Limestone and Hodder Mudstone Formation (undifferentiated))		Braddup Connection – open cut section connecting the existing pipeline with the Proposed Marl Hill Tunnel	**High** For the most part, 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 south of the open-cut section where the susceptibility of groundwater flooding is		The open-cut construction method proposed for the Braddup 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
			classified as Moderate to High (potential for flooding of below ground properties). Land uses: farm access track (medium sensitivity); rough grazing farmland (low sensitivity); existing valve house / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.				
Secondary A Bedrock Aquifer (Pendleton Formation)		Braddup Connection – open cut section connecting the existing pipeline with the Proposed Marl Hill Tunnel	**High** For the most part, 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 south of the open-cut section where the susceptibility of groundwater flooding is classified as Moderate to High (potential for flooding of below ground properties). Land uses: farm access track (medium sensitivity); rough grazing farmland (low sensitivity); existing valve house / infrastructure (high sensitivity).		The open-cut construction method proposed for the Braddup 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

Jacobs

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.				

10. Fluvial flood risk – Decommissioning Phase Marl Hill Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Bashall Brook Ordinary Watercourse		The existing overflow structure remains in situ and discharges to this watercourse.	**Very High** Flood Zone 2 and 3 indicating a risk of fluvial flooding greater than 1 % AEP. Agricultural land is located downstream of the existing overflow including a farm building on Cross Lane.		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 Bashall Brook. The continuous discharge of groundwater has the potential to increase fluvial 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 Bashall Brook has been undertaken. This indicates that the discharge from the overflow would be less than 1 % of the QMED flow within the watercourse. Therefore, it is considered that the impact on flood risk along the Bashall Brook to downstream receptors would be **negligible**.		Neutral

11. Groundwater flood risk – Decommissioning Phase Marl Hill Section

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Secondary Undifferentiated		Existing aqueduct	**High**		Once the new aqueduct is operational, the existing aqueduct will be decommissioned but remain in place. Ingress of groundwater into the		

Flood Source		Proposed Scheme Element	Likelihood / Importance		Magnitude of Change		Significance
Name	Type		Score	Justification	Score	Justification	Score
Superficial aquifer (Till) Secondary A Superficial Aquifers (River Terrace Deposits and Alluvial Fan Deposits) Unproductive Strata (Peat) Secondary A Bedrock Aquifers (Hodder Mudstone Formation, Pendleton Formation, Pendleside Limestone Formation, Hodderense Limestone Formation and Bowland Shale Formation)	Groundwater flooding Groundwater flooding Groundwater flooding Groundwater flooding	running between Bonstone and Braddup Compounds		For the majority of the existing aqueduct, there is a Very Low to Low potential risk of groundwater emergence (limited potential for groundwater flooding to occur) (BGS, 2020) (low sensitivity). Small areas in the north, centre and south of the existing route are categorised as Moderate to High (potential for groundwater flooding of properties situated below ground level) (medium sensitivity) and Very High (potential for groundwater flooding to occur at surface level) (high sensitivity). Land uses: rough grazing farmland (low sensitivity); farm access tracks (medium sensitivity); high quality productive wheat fields (medium sensitivity); farm buildings/barns (high sensitivity); existing valve houses / infrastructure (high sensitivity). The most conservative sensitivity for this element is high.		existing aqueduct would be likely to occur over time at an estimated rate of 15.28 to 26.49 l/s for the entire existing Marl Hill section which is about 4.3 km long, equating to an ingress rate of 3.57E-03 to 6.19E-03 l/s/m. This would be expected to generate a small, long-term groundwater drawdown over the length of the aqueduct in the Proposed Marl Hill Section, which would be beneficial in terms of groundwater flooding. This would be expected to present a **minor beneficial** change.	Slight (beneficial)

Annexe B: EIA Assessment Criteria

B.1 Baseline Sensitivity

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

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 changes that would remain for the full duration of the operational life of the scheme or temporary changes that would be limited in duration to the construction period
- 'Embedded' mitigation measures that form part of an optimised design used to manage the likely significant flood risk effects.

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.

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 do 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

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, then additional mitigation would be required. Any effects that cannot be mitigated would be recorded as residual effects.

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 – The Proposed Marl Hill Section Location and Layout

Figure 2 – The Flood Map for Planning

Figure 3 – The Risk of Flooding from Surface Water Map

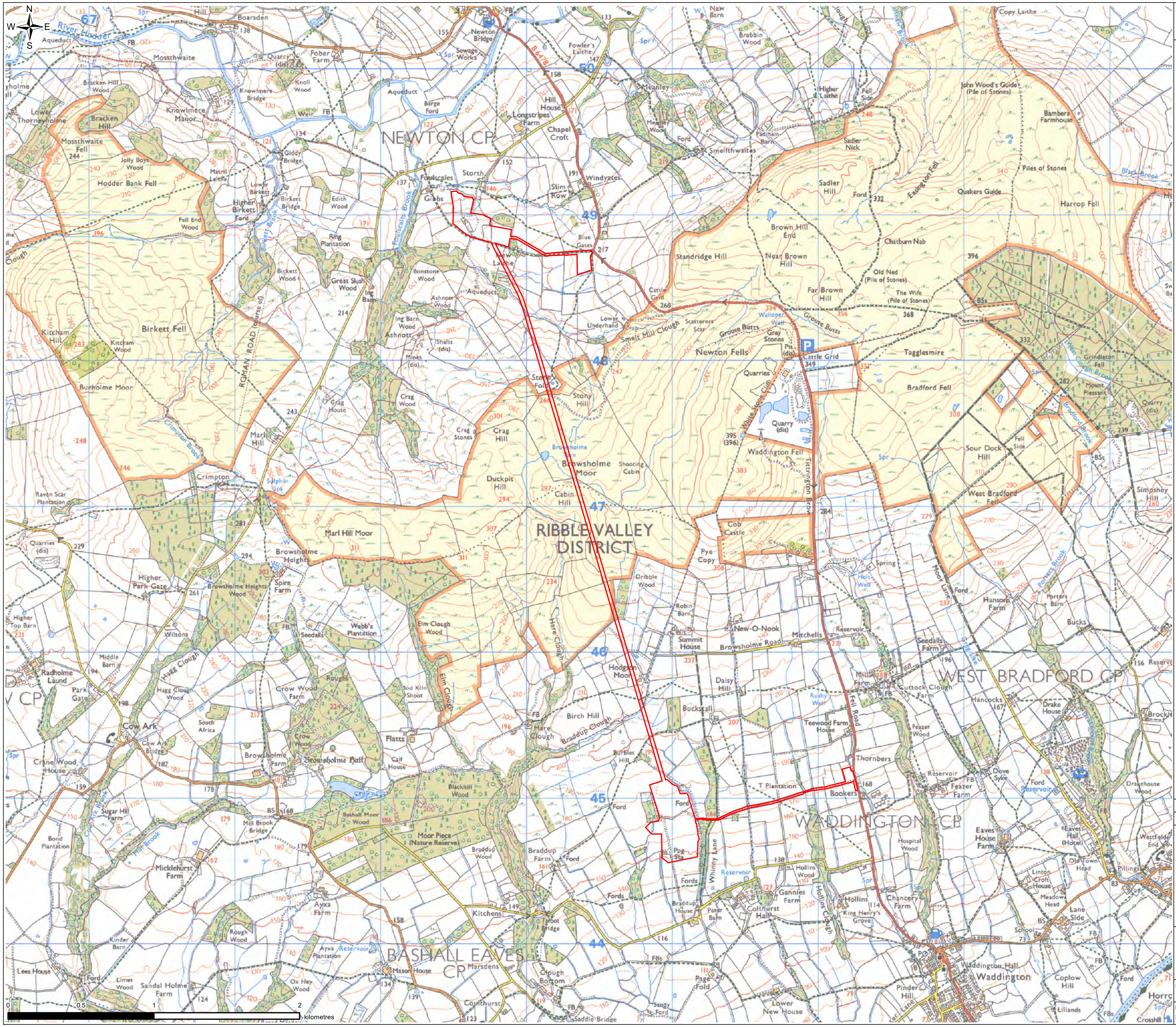
Figure 4 – Areas Susceptible to Groundwater

Refer to Planning Application drawings for further details on drainage.

PROPOSED BONSTONE COMPOUND PERMANENT SITE LAYOUT (Ref: 80061155-01-JAC-TR4-97-DR-C-00002)

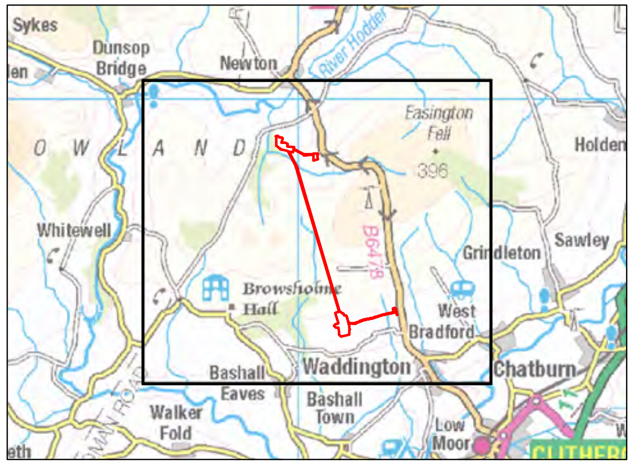
PROPOSED BRADDUP COMPOUND PERMANENT SITE LAYOUT (Ref: 80061155-01-JAC-TR4-97-DR-C-00004)

FIGURE 1



Legend

Planning Application Boundary



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SCHEME OVERVIEW
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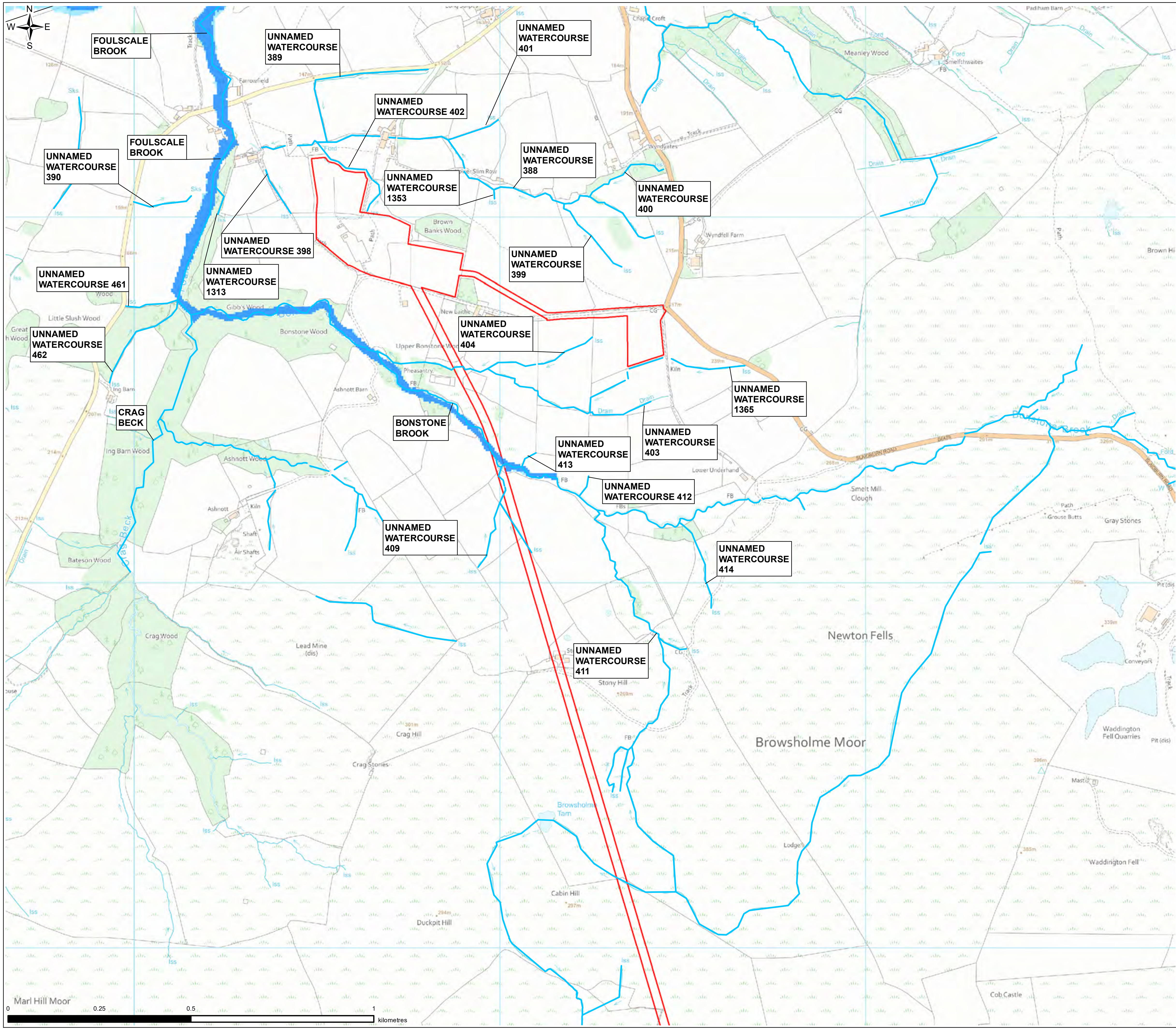
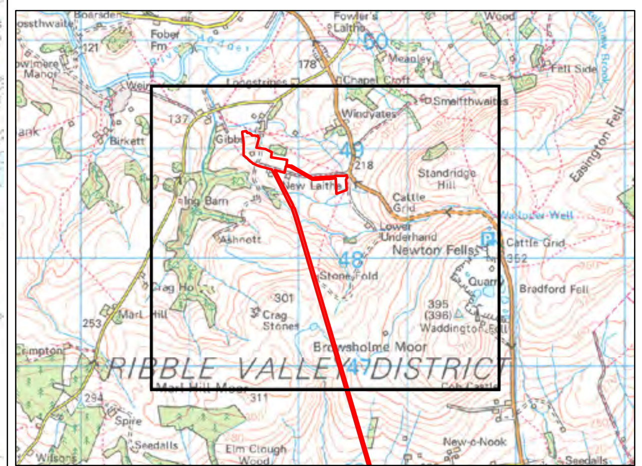
RVBC-MH-FIG-FRA-001	0

FIGURE 2



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



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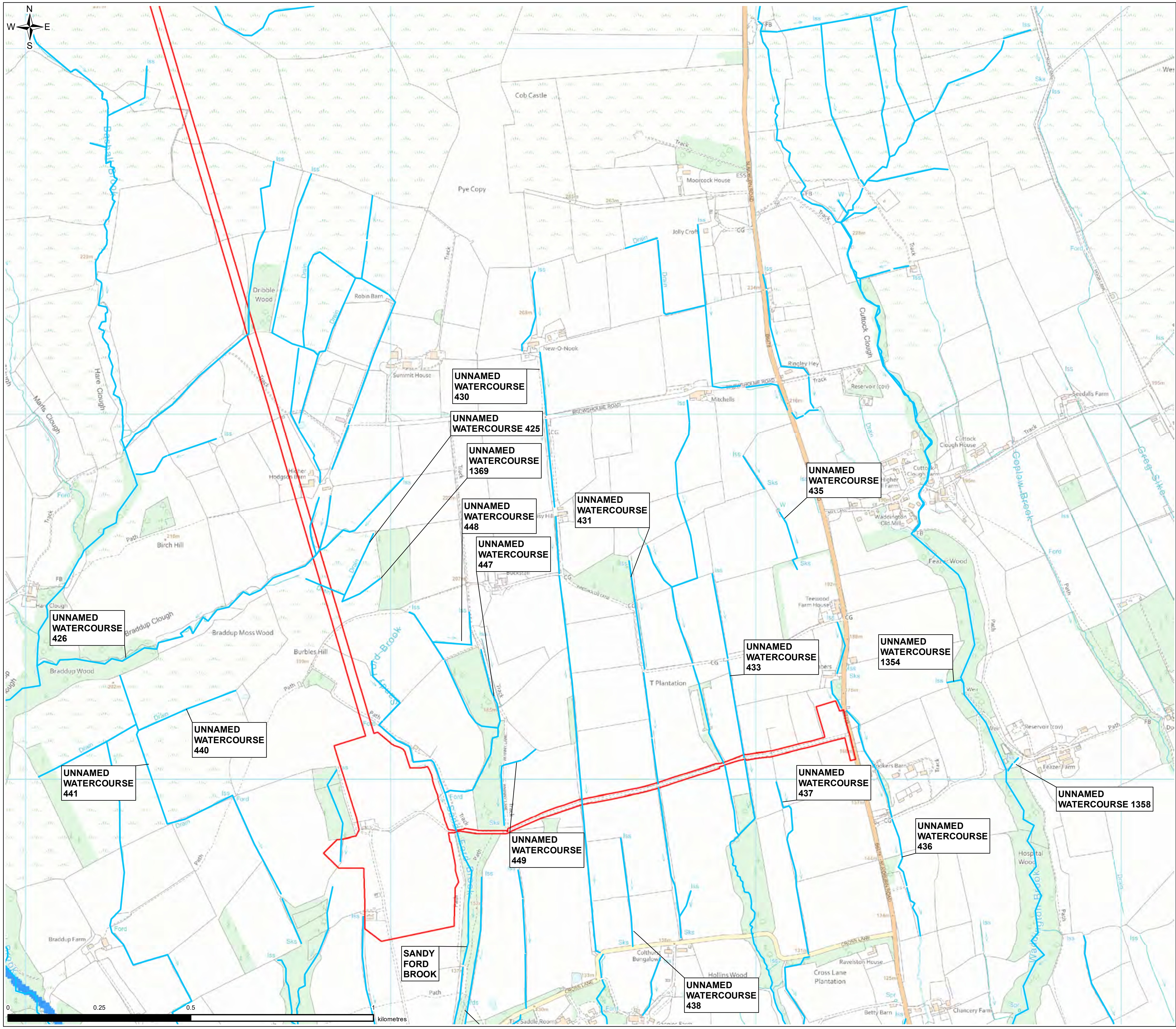
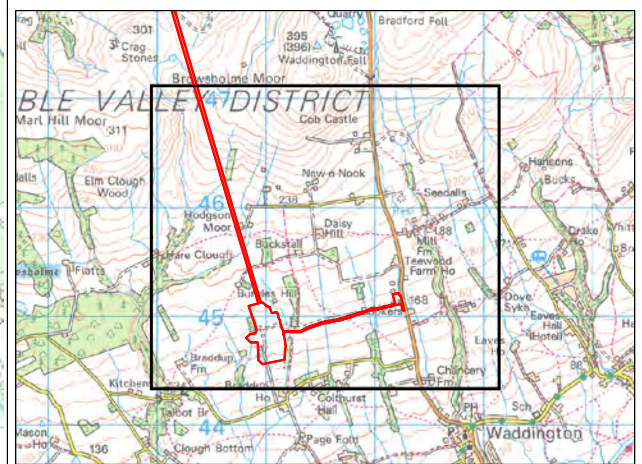


FIGURE 2

Legend

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



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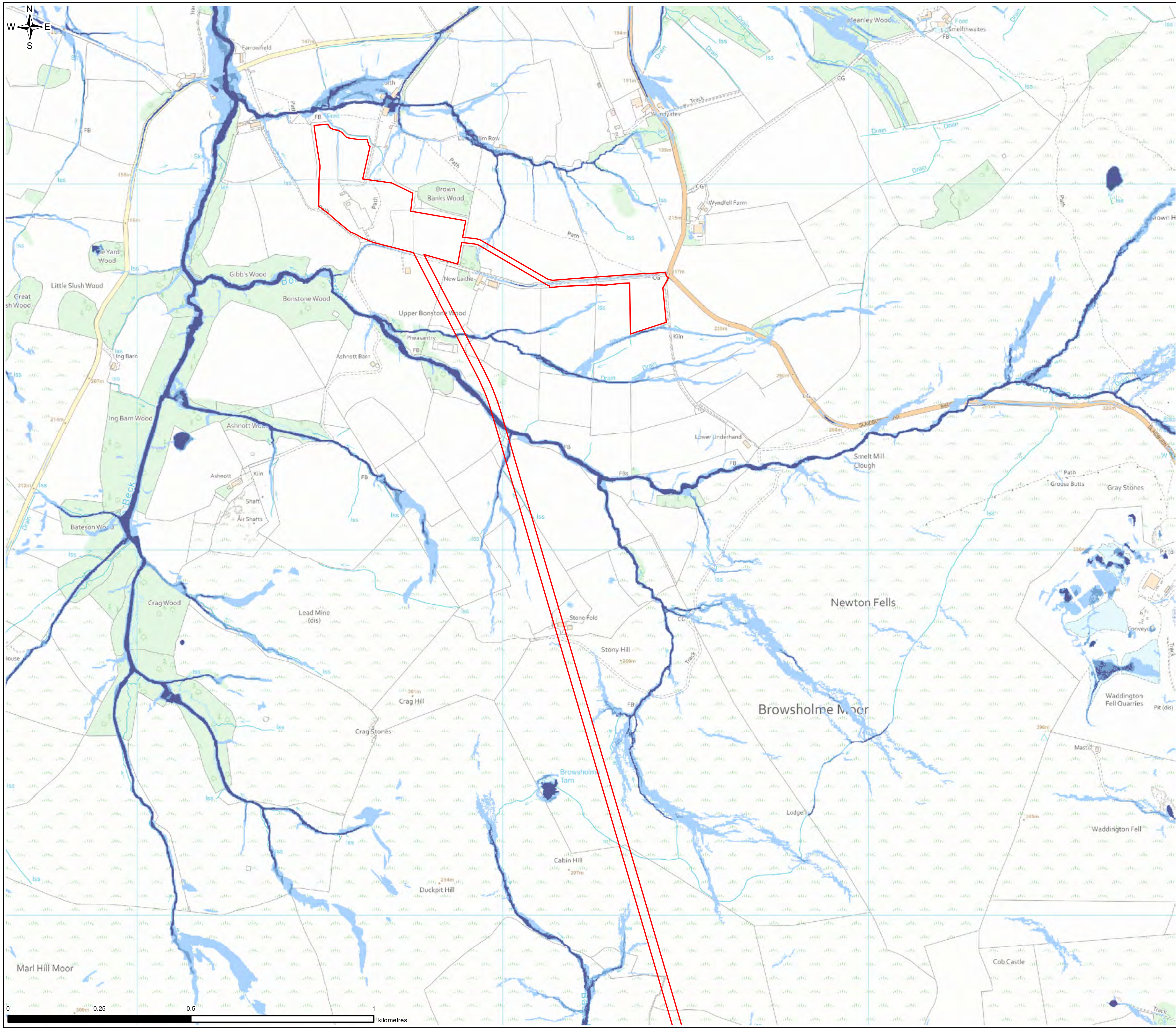

FIGURE 3

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

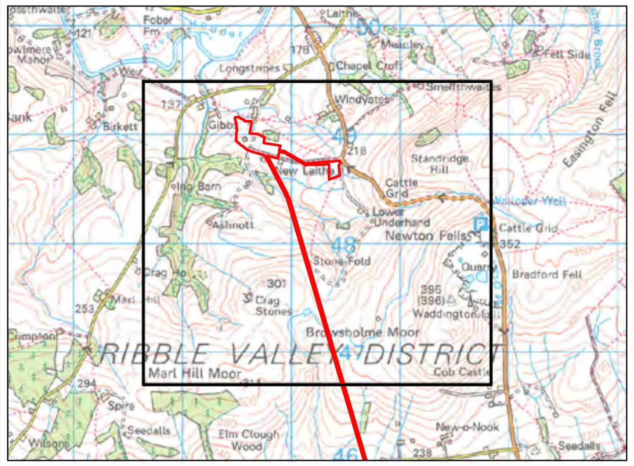

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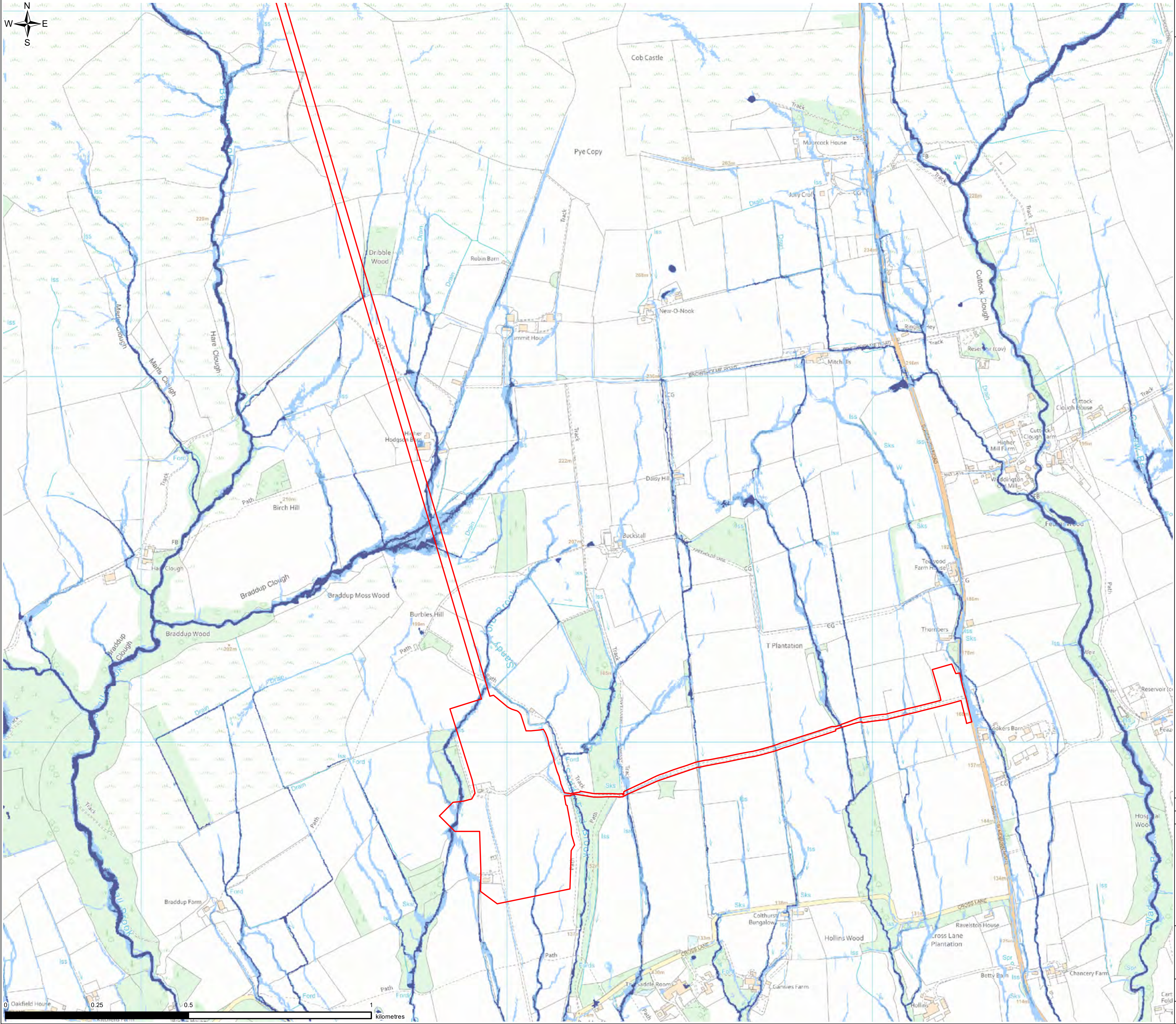
FIGURE 3



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

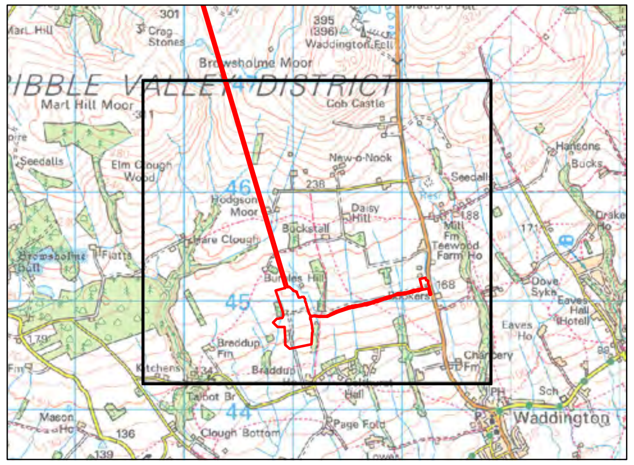


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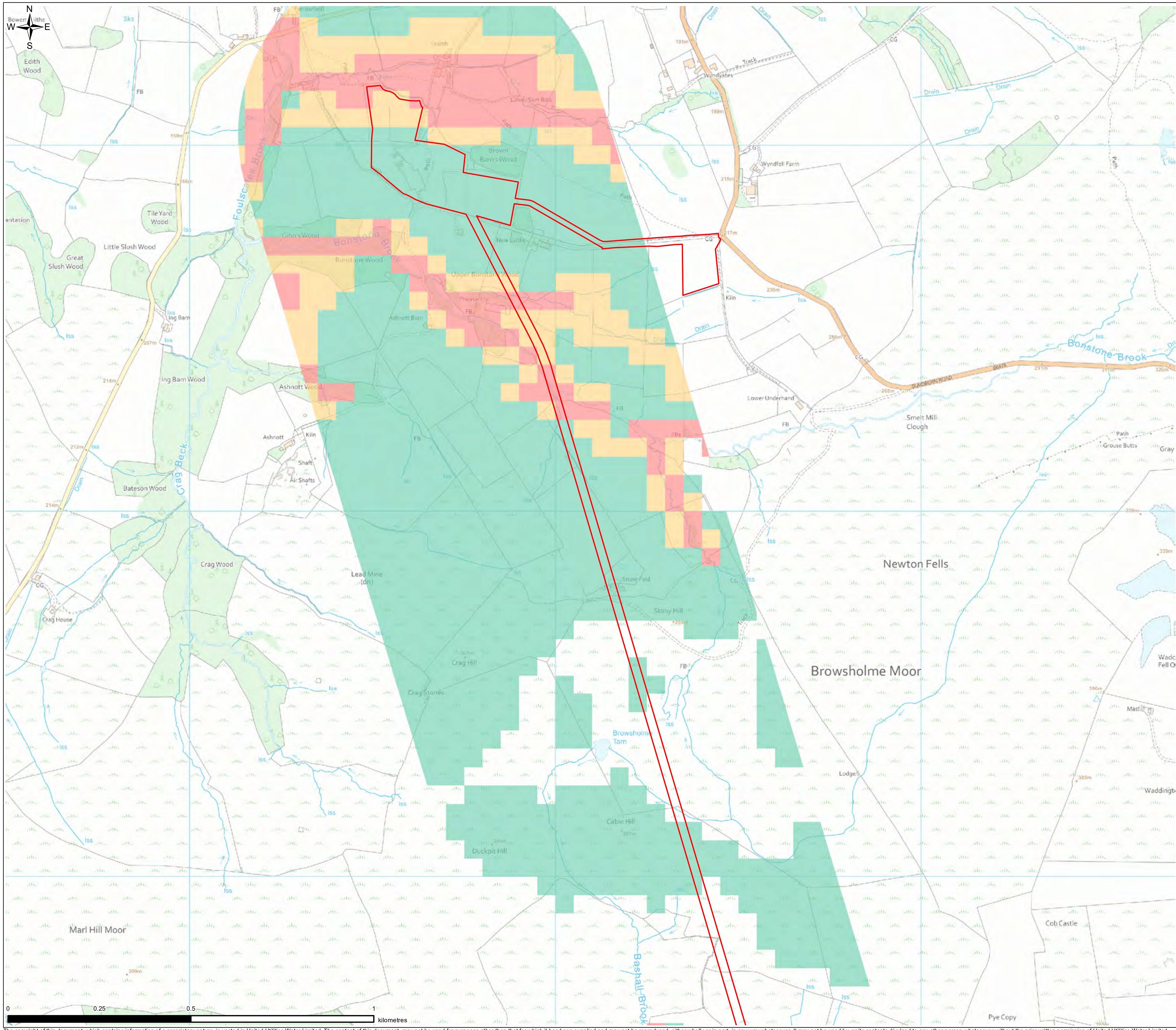
FIGURE 4



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Planning Application Boundary

Groundwater Flooding Susceptibility Areas

Very Low - Low

Moderate - High

Very High

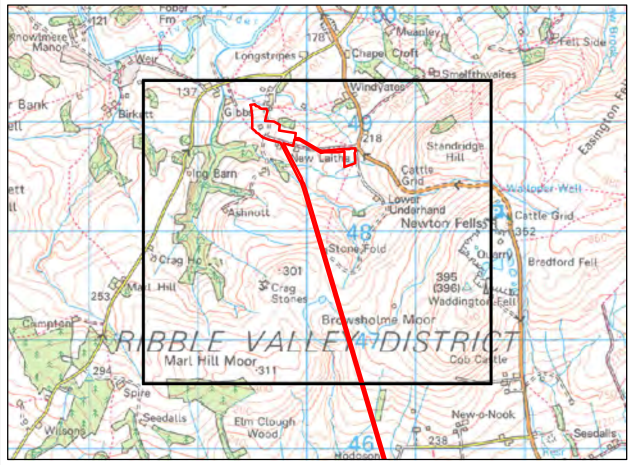

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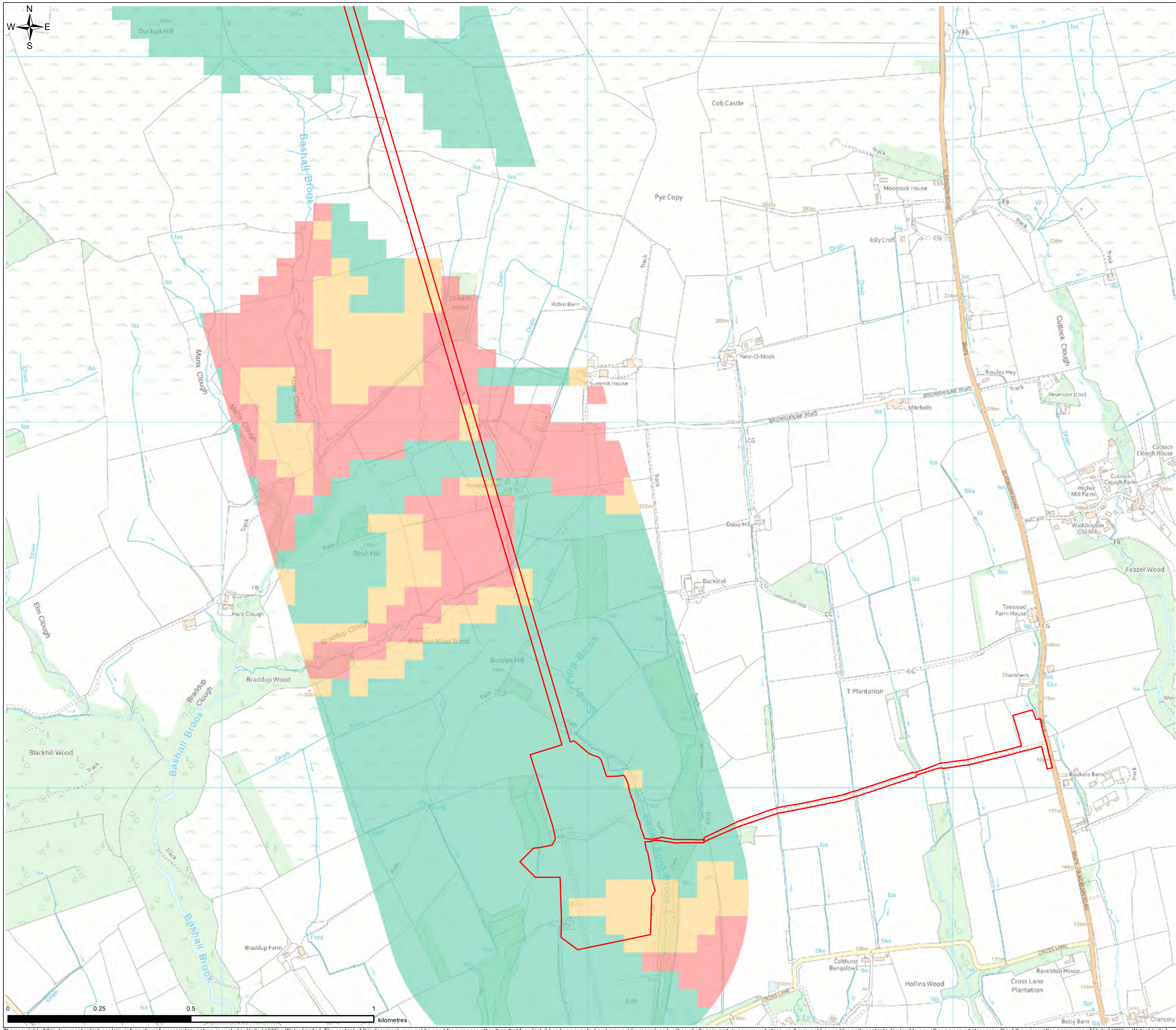
FIGURE 4



Legend

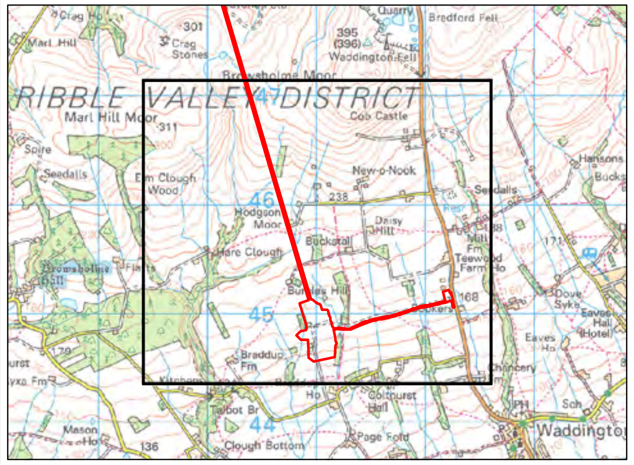
Planning Application Boundary

Groundwater Flooding Susceptibility Areas

Very Low - Low

Moderate - High

Very High



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Annexe D: Drainage Assessment

Appendix M

Haweswater Aqueduct Resilience Programme

Surface Water Drainage Assessment

Date: 7th May 2020

Version: 1

Version	Purpose / summary of changes	Date	Written By	Checked By	Approved By
1	Task 3 Deliverable	07/05/2020	M Lloyd		

Appendix M

Contents

Appendix M

1. Introduction

During establishment of each tunnel shaft/portal site it will be necessary to construct concrete or blacktop surfaces to provide a tunnel working platform, an offices/welfare/parking area and a temporary haul road. These will introduce impermeable surfaces to the existing greenfield sites, resulting in increased volumes of surface water runoff during rainfall events.

To comply with planning legislation it is necessary to apply the principles of Sustainable Drainage Systems (SuDS) to any significant development, including the temporary sites found on this project.

The SuDS approach involves slowing down and reducing the quantity of surface water runoff from a developed area to manage downstream flood risk, and reducing the risk of that runoff causing pollution. This is achieved by harvesting, infiltrating, slowing, storing, conveying and treating runoff on site and, where possible, on the surface rather than underground.

Owing to the temporary nature of the tunnel shaft/portal sites, many of the SuDS techniques are not appropriate. However, the following techniques are relevant:

- Infiltration drainage;
- Attenuation storage.

Each site has been assessed to determine how best to apply the above techniques, and the detailed procedure is discussed below.

Additional water flows will be generated by the tunnelling activities and flow rates have been estimated by the tunnelling team. An allowance has been included in the drainage assessment of each site, to take account of these estimated flows.

Flood risk has also been assessed for each tunnel shaft/portal site. This is not intended to represent a formal flood risk assessment (as required for a planning application) but can be used to inform decisions regarding the site layout.

2. Assessment Approach

Each tunnel shaft/portal site has been assessed using the following procedure:

i. Determine the likelihood and extent of flood risk from:
   - Fluvial sources (i.e. rivers and other watercourses);
   - Surface water runoff (i.e. overland flow).

ii. Confirm the existing surface water drainage regime:
   - Determine the local soil type and its standard percentage runoff value (using www.uksuds.com);
   - Reference to Ordnance Survey 1:2500 mapping, overlain with Lidar-derived 1 metre contours, to determine drainage flow paths and receiving watercourses;
   - Using Google Earth aerial photography for visual confirmation of the drainage flow paths and watercourses.

iii. Quantify mitigation measures to protect this drainage regime:
   - Quantify the impermeable areas that will be created;
   - Consider the suitability of infiltration drainage systems (e.g. soakaways, roadside swales) for selected areas;
   - Where an infiltration drainage system may be effective, confirm that the site does not lie within a groundwater source protection zone (https://magic.defra.gov.uk/MagicMap.aspx);
   - For the remaining areas, obtain a preliminary attenuation storage volume and acceptable discharge rate;
   - Increase the attenuation storage arrangements by an appropriate factor to allow for additional water flows arising from the tunnelling activities.
   - Assess the topography to identify a suitable location for the attenuation storage and water treatment plant, plus a drainage route to a suitable watercourse. Gravity drainage systems are preferred, with pumped systems only being shown as a last resort in particularly difficult situations.
   - The point of discharge is selected (using OS mapping, Lidar contours and Google Earth information) where the watercourse appears to have sufficient capacity to receive the planned discharges. This will, in due course, require site survey to confirm assumptions that have had to be made.

3. Basis of Analysis

3.1 Infiltration Drainage

When detailed soil infiltration rates are not available, it is usual to consider soils with a standard percentage runoff of 30% (or less) to have potential for infiltration drainage systems. This approach has been adopted for this high level assessment.

A preliminary soakaway volume estimate has been produced for each soakaway location, to confirm land availability for the required soakaway dimensions. However each calculation is based on an assumed local infiltration rate, which may be highly inaccurate. For this reason the calculated soakaway dimensions are not quoted in this report.

It is recommended that infiltration tests be conducted at locations where infiltration systems are being considered, in order to confirm (or exclude) their application.

Where infiltration drainage is proposed, a check has been made (using https://magic.defra.gov.uk/MagicMap.aspx) to confirm that the site is not in a groundwater source protection zone.

3.2 Attenuation Storage

Attenuation storage volume estimates have been obtained using a storage assessment method developed by HR Wallingford (www.uksuds.com/drainage-calculation-tools/surface-water-storage).

The surface water storage volume estimation tool is based on correlations between storage requirements and hydrological and hydraulic characteristics of sites. This methodology is based on the premise that the flow rate discharge constraints for storm water runoff from the site are defined by the greenfield runoff rates for the 1 year, 30 year and 100 year return periods.

The drainage design criteria applied are in line with best practice in the SuDS Manual and the SuDS Standards in England, Wales and Northern Ireland.

The methodology takes into consideration the partial use of infiltration, along with whether or not permeable areas contribute runoff. It also makes allowances for different hydrological regions, climate change and other factors.

A minimum discharge rate of 5 l/s has been applied, as this is generally regarding as a practical minimum for static flow controls. For some of the sites this flow rate is larger than the calculated greenfield runoff from the catchment area.

3.3 Generated Water Flows

Additional water flows will be generated by the tunnelling activities. The tunnelling team has prepared an estimate of these flows for each tunnel shaft/portal site, and this has previously been supplied to United Utilities. This report does not consider these generated flows in detail, but an indicative flow allowance is included for each shaft/portal site in Table 1.

It is anticipated that water recycling will be implemented within each tunnelling shaft/portal site, to be used for washdown activities. This will significantly reduce the demand for potable water and will also reduce the flow rate of generated water that has to discharged to a watercourse.

3.4 Water Quality

The tunnelling activities will result in contaminated runoff from the working platform. These areas are considered unsuitable for infiltration owing to the risk of introducing contaminants into the underlying soils. So it is recommended that these areas be drained via an attenuation lagoon/tank to a packaged water treatment plant (WTP), to ensure that the WTP receives a steady inflow (avoiding the peak flows caused by intense rainfall events). The cleaned water will then be discharged to the receiving watercourse.

Runoff from temporary haul roads, and also the offices/welfare/parking areas, will be relatively uncontaminated. This water can be drained either by infiltration (where possible), or into an attenuation lagoon/tank before discharge to the receiving watercourse. Sometimes this runoff will also pass through the water treatment plant, where the site layout favours this arrangement.

4. Results

The results of these analyses are included in Table 1 below.

For each site, these results provide an indication of whether infiltration systems may be appropriate for parts of the proposed impermeable areas. For areas that cannot be drained by infiltration, an estimate of the required attenuation storage volume is given along with the allowable discharge rate (as discussed above).

The site layout drawings (see Appendix E) include the key features of each drainage system, and the location of each drainage outfall.

For each tunnel shaft/portal site this report also includes the following:

i. **Flood Map For Planning** (https://flood-map-for-planning.service.gov.uk)

A plan showing the following fluvial flood risk zones:

Flood Zone	Definition
Zone 1 Low Probability	Land having a less than 1 in 1,000 annual probability of river flooding. (Shown as 'clear' on the Flood Map – all land outside Zones 2 and 3)
Zone 2 Medium Probability	Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding. (Land shown in light blue on the Flood Map)
Zone 3a High Probability	Land having a 1 in 100 or greater annual probability of river flooding. (Land shown in dark blue on the Flood Map)
Zone 3b The Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map)

ii. **Long Term Flood Risk Map** (https://flood-warning-information.service.gov.uk/long-term-flood-risk)

A plan showing the following surface water flood risk categories:

Flood Category	Definition
Very Low Risk	Land having a less than 1 in 1,000 annual probability of surface water flooding. (Shown as 'clear' on the flood map – all land outside the Low, Medium and High Risk Zones)
Low Risk	Land having between a 1 in 100 and 1 in 1,000 annual probability of surface water flooding. (Land shown in light blue on the flood map)
Medium Risk	Land having between a 1 in 30 and 1 in 100 annual probability of surface water flooding. (Land shown in medium blue on the flood map)
High Risk	Land having greater than 1 in 30 annual probability of surface water flooding. (Land shown in dark blue on the flood map)

iii. **Surface Water Storage Volume Estimation** (https://www.uksuds.com/drainage-calculation-tools/surface-water-storage)

A one page report summarises the hydrological and hydraulic analysis, as described in the 'Attenuation storage' section.

Table 1 - Tunnelling shaft/portal sites - Summary of drainage assessment

SITE DETAILS			FLOOD RISK		SOIL DATA & HYDROGEOLOGY				IMPERMEABLE CATCHMENT			ATTENUATION DATA		GENERATED FLOWS
Site name	Drive / Reception	Coords (shaft) E, N	Fluvial flood risk	Surface water flood risk	SOIL type	SPR %	Source Protection Zone	Suitability for infiltration drainage	Impermeable area ha	Area drained to infiltration ha	Area drained to attenuation pond/tank ha	Attenuation storage volume cu.m	Pond/tank maximum discharge rate l/s	Estimated discharge from tunnelling activities l/s
TR1-A	Reception	355099, 495089	Zone 1 (low risk)	Very low risk	2	30%	No	Yes	1.11	0.61	0.5	280	5.0	2.5
TR1-C	Drive	356540, 492325	Zone 1 (low risk)	Very low risk	2	30%	No	Yes	1.05	0.24	0.81	675	5.0	4
TR2-A	Reception	357580, 489485	Zone 1 (low risk)	Very low risk	2	30%	No	Yes	0.5	0.12	0.38	193	5.0	2.5
TR2-B	Drive	359600, 483925	Zone 1 (low risk)	Very low risk	2	30%	No	Yes	1.24	0.51	0.73	426	5.0	4
TR2-B-1	Reception	360253, 483533	Zone 1 (low risk)	Very low risk	2	30%	No	Yes	0.77	0.14	0.63	347	5.0	2.5
TR3-A	Reception	363590, 465537	Zone 1 (low risk)	Very low risk	4	47%		No	0.61	0	0.61	481	6.3	2.5
TR3-C	Drive	368914, 450480	Zone 1 (low risk)	Very low risk	4	47%		No	0.8	0	0.8	568	9.7	4
TR4-A	Reception	369700, 448918	Zone 1 (low risk)	Very low risk	4	47%		No	0.53	0	0.53	366	6.2	2.5
TR4-B	Drive	371012, 445010	Zone 1 (low risk)	Very low risk	4	47%		No	0.97	0	0.97	706	10.0	4

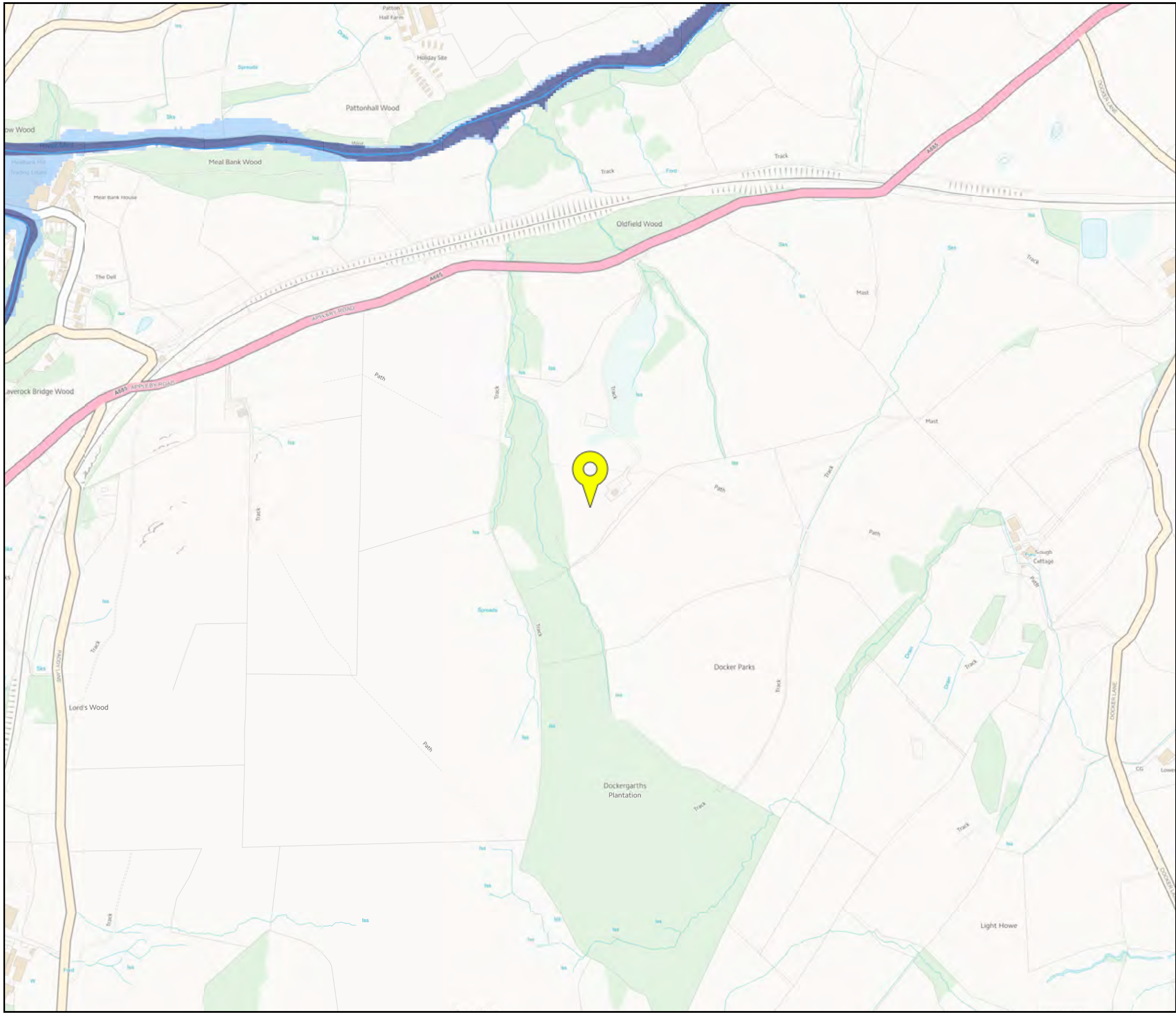
SITE DETAILS			FLOOD RISK		SOIL DATA & HYDROGEOLOGY				IMPERMEABLE CATCHMENT			ATTENUATION DATA		GENERATED FLOWS
Site name	Drive / Reception	Coords (shaft) E, N	Fluvial flood risk	Surface water flood risk	SOIL type	SPR %	Source Protection Zone	Suitability for infiltration drainage	Impermeable area ha	Area drained to infiltration ha	Area drained to attenuation pond/tank ha	Attenuation storage volume cu.m	Pond/tank maximum discharge rate l/s	Estimated discharge from tunnelling activities l/s
TR5-A	Reception	377077, 430167	Zone 1 (low risk)	Medium risk	4	47%		No	0.5	0	0.5	284	5.0	2.5
TR5-I	Dual drive	379724, 422064	Zone 1 (low risk)	Very low risk	5	53%		No	1.7	0	1.7	1055	23.0	6
TR5-I	Offices /welfare /parking		Zone 1 (low risk)	Very low risk	5	53%		No	0.7	0	0.7	435	9.5	---
TR6-G	Reception	382229, 412158	Zone 1 (low risk)	Very low risk	5	53%		No	0.5	0	0.5	264	5.5	2.5

Appendix M

Haweswater Aqueduct Resilience Programme

Shaft / Portal Sites – Drainage Assessment Data

TR1-A	Reception Site
TR1-C	Drive Site
TR2-A	Reception Site
TR2-B	Drive Site
TR2-B1	Drive Site
TR3-A	Reception Site
TR3-C	Drive Site
TR4-A	Reception Site
TR4-B	Drive Site
TR5-A	Reception Site
TR5-I	Dual Drive Site
TR6-G	Reception Site



Environment Agency

Flood map for planning

Your reference
TR1-A

Location (easting/northing)
355083/495116

Scale
1:10000

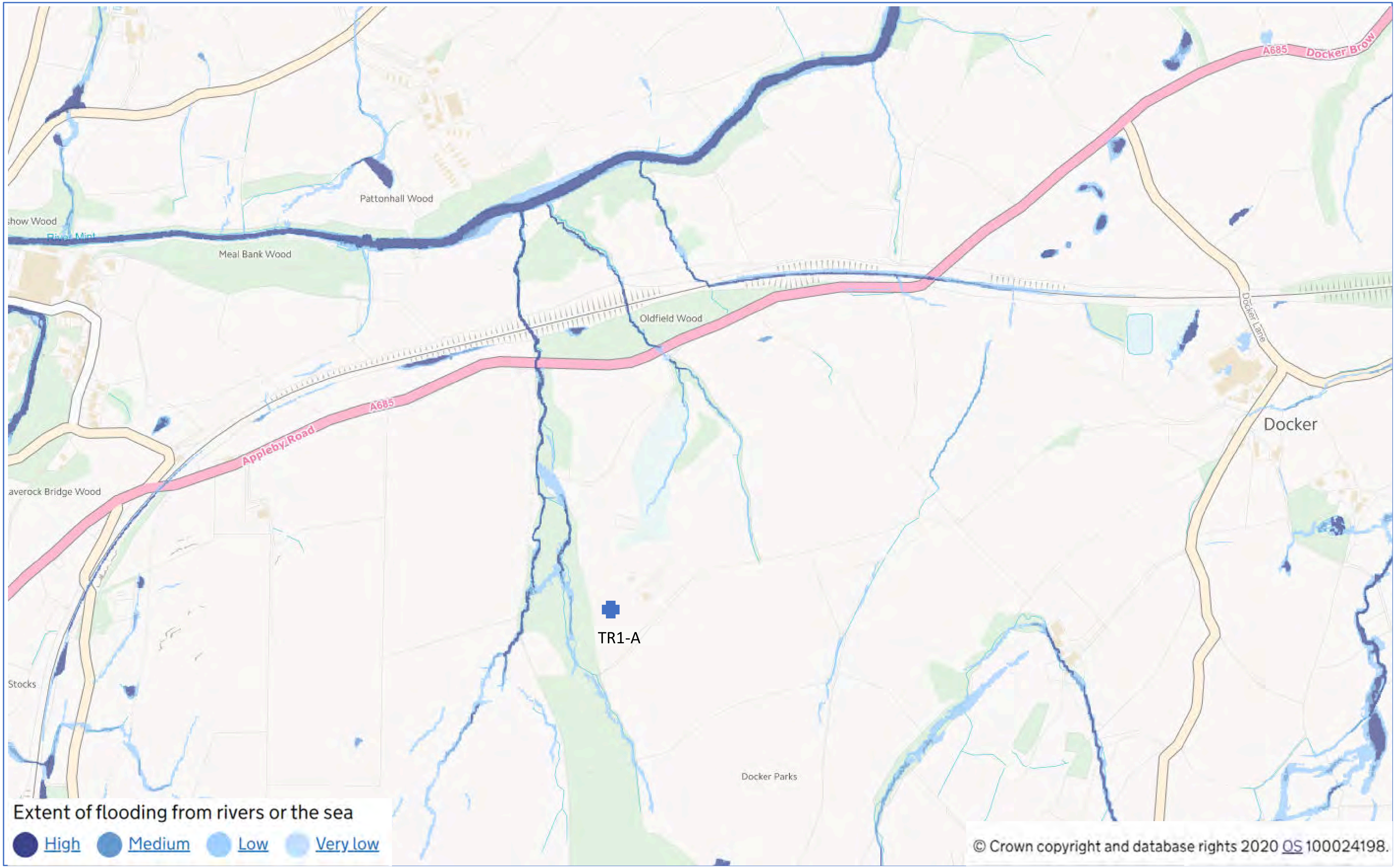
Created
7 May 2020 13:25

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR1-A

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR1-A
Site location:	LA8 0DA

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	54.34858° N
Longitude:	2.69099° W
Reference:	2563754087
Date:	Apr 21 2020 12:34

Site characteristics

Total site area (ha):	0.5
Significant public open space (ha):	0
Area positively drained (ha):	0.5
Impermeable area (ha):	0.5
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.5
Net impermable area for storage volume design (ha):	0.5
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	2	2
SPR:	0.3	0.3

Hydrological characteristics

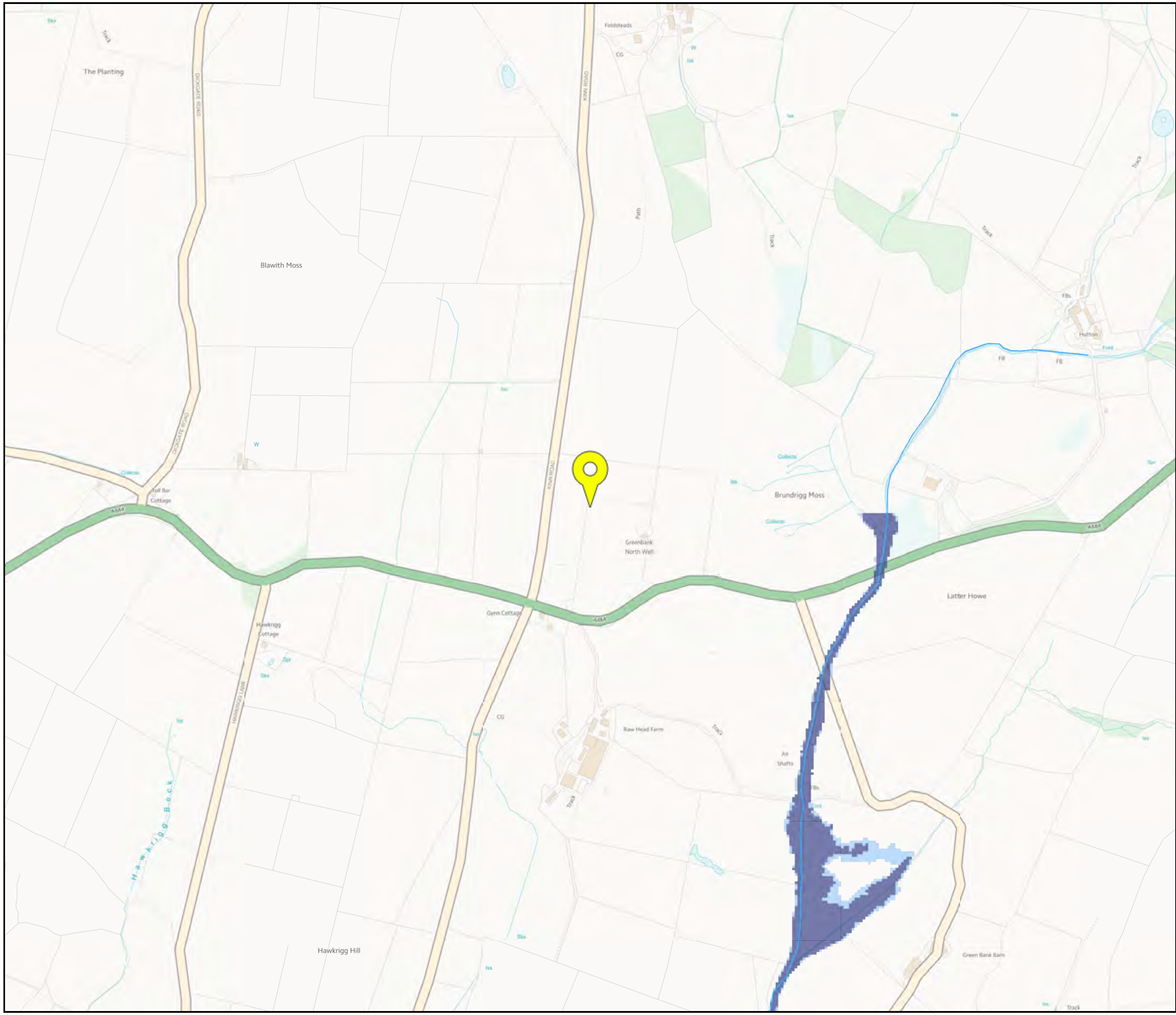
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	101.97
FEH / FSR conversion factor:	1	0.99
SAAR (mm):	1428	1428
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	2.1	2.1
Q_{BAR} for net site area (l/s):	2.1	2.1

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5	5
1 in 30 years (l/s):	5	5
1 in 100 year (l/s):	5	5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	280	276
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	280	276



Environment Agency

Flood map for planning

Your reference
TR1-C

Location (easting/northing)
356540/492325

Scale
1:10000

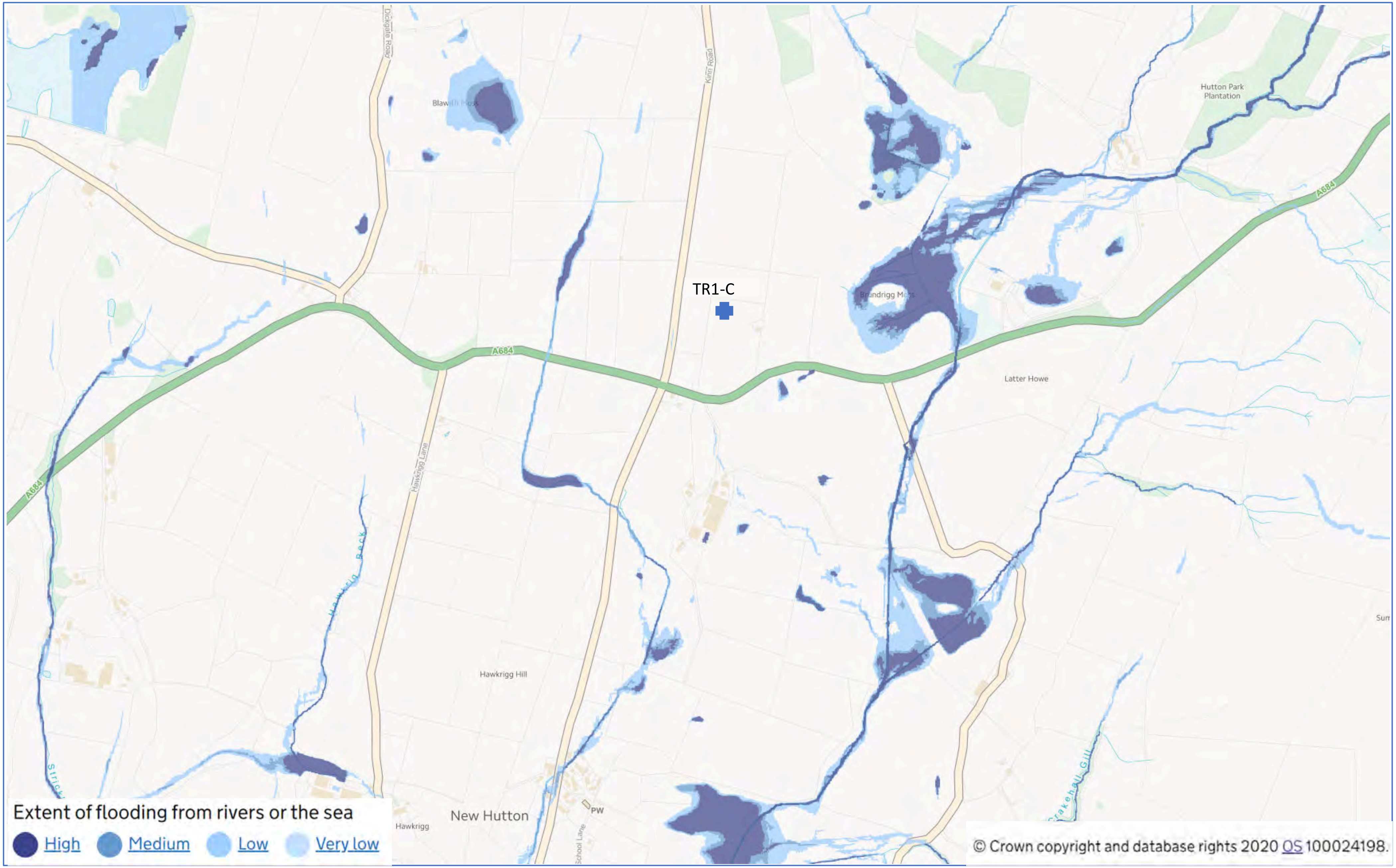
Created
7 May 2020 14:43

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR1-C

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR1-C
Site location:	LA8 0AR

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance “Rainfall runoff management for developments”, SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	54.32451° N
Longitude:	2.66833° W
Reference:	788290056
Date:	Apr 22 2020 08:02

Site characteristics

Total site area (ha):	0.81
Significant public open space (ha):	0
Area positively drained (ha):	0.81
Impermeable area (ha):	0.81
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.81
Net impermable area for storage volume design (ha):	0.81
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	2	2
SPR:	0.3	0.3

Hydrological characteristics

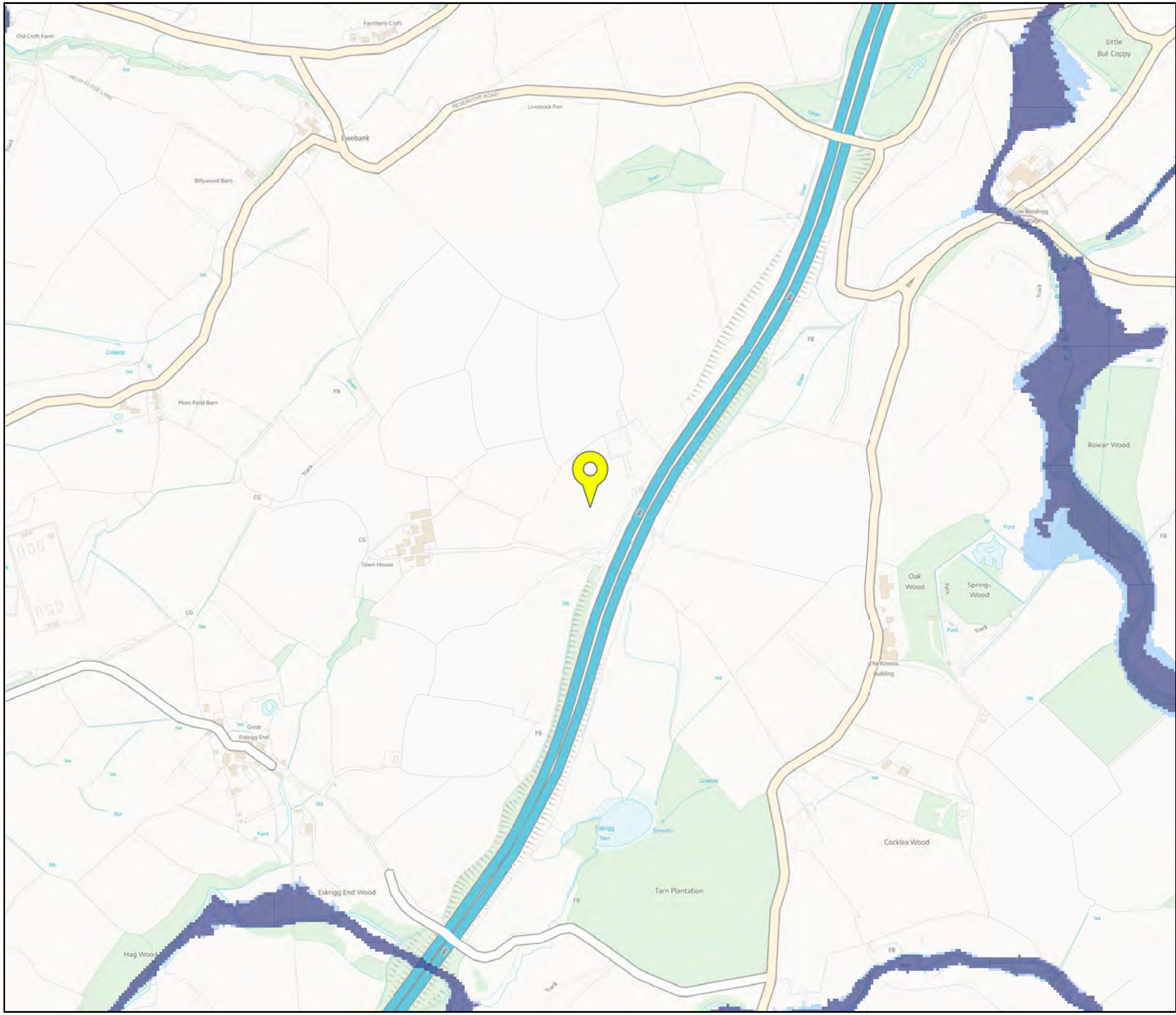
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	101.97
FEH / FSR conversion factor:	1.04	0.99
SAAR (mm):	1418	1418
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	3.37	3.37
Q_{BAR} for net site area (l/s):	3.37	3.37

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5	5
1 in 30 years (l/s):	5	5
1 in 100 year (l/s):	5	5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	734	675
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	734	675



Environment Agency

Flood map for planning

Your reference
TR2-A

Location (easting/northing)
357580/489485

Scale
1:10000

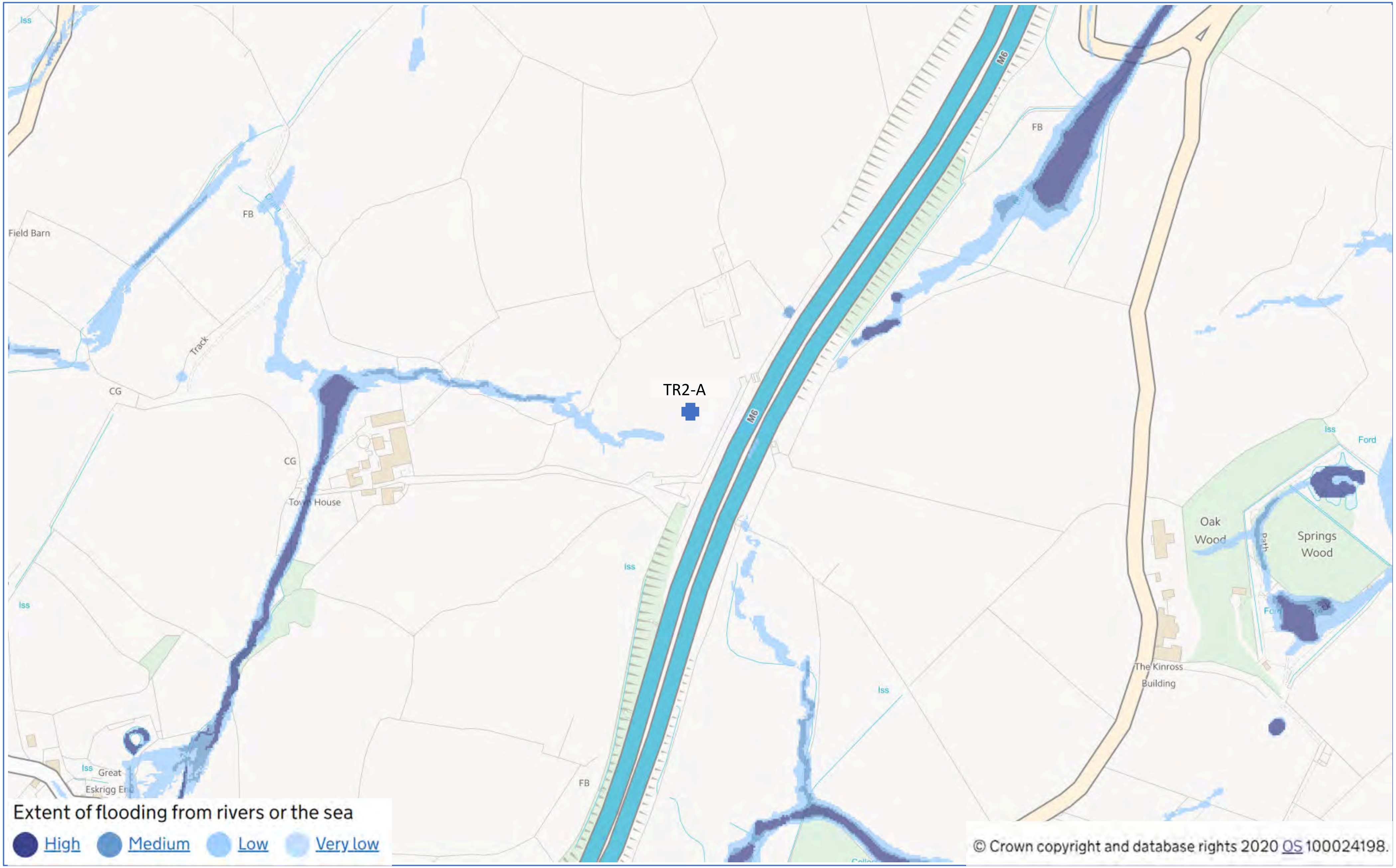
Created
7 May 2020 13:47

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR2-A

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR2-A
Site location:	LA8 0NR

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	54.30042° N
Longitude:	2.65254° W
Reference:	3267767033
Date:	Apr 20 2020 14:41

Site characteristics

Total site area (ha):	0.38
Significant public open space (ha):	0
Area positively drained (ha):	0.38
Impermeable area (ha):	0.38
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.38
Net impermable area for storage volume design (ha):	0.38
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	2	2
SPR:	0.3	0.3

Hydrological characteristics

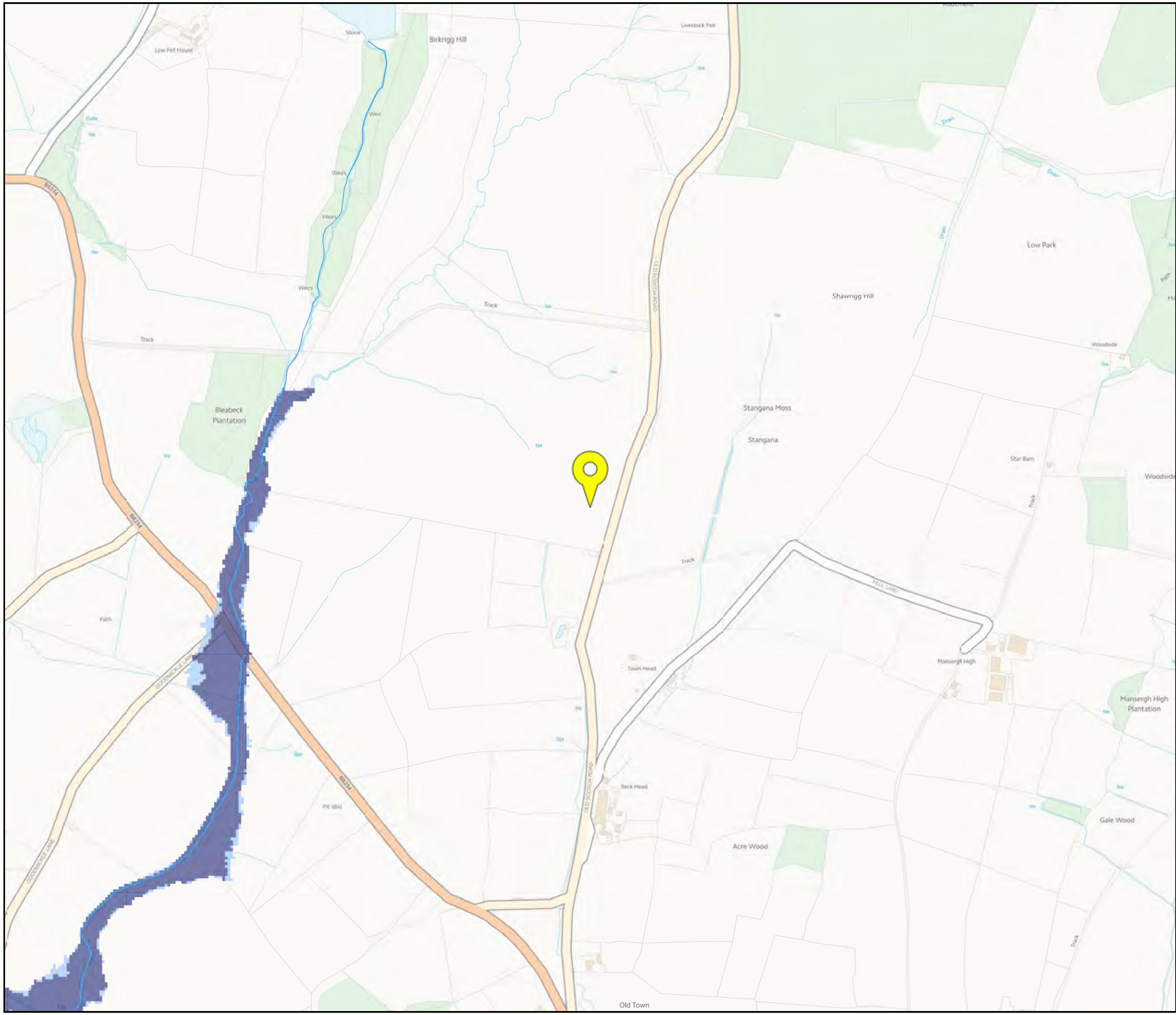
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	101.97
FEH / FSR conversion factor:	1.06	0.99
SAAR (mm):	1375	1375
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	1.53	1.53
Q_{BAR} for net site area (l/s):	1.53	1.53

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5	5
1 in 30 years (l/s):	5	5
1 in 100 year (l/s):	5	5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	193	172
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	193	172



Environment Agency

Flood map for planning

Your reference
TR2-B

Location (easting/northing)
359600/483925

Scale
1:10000

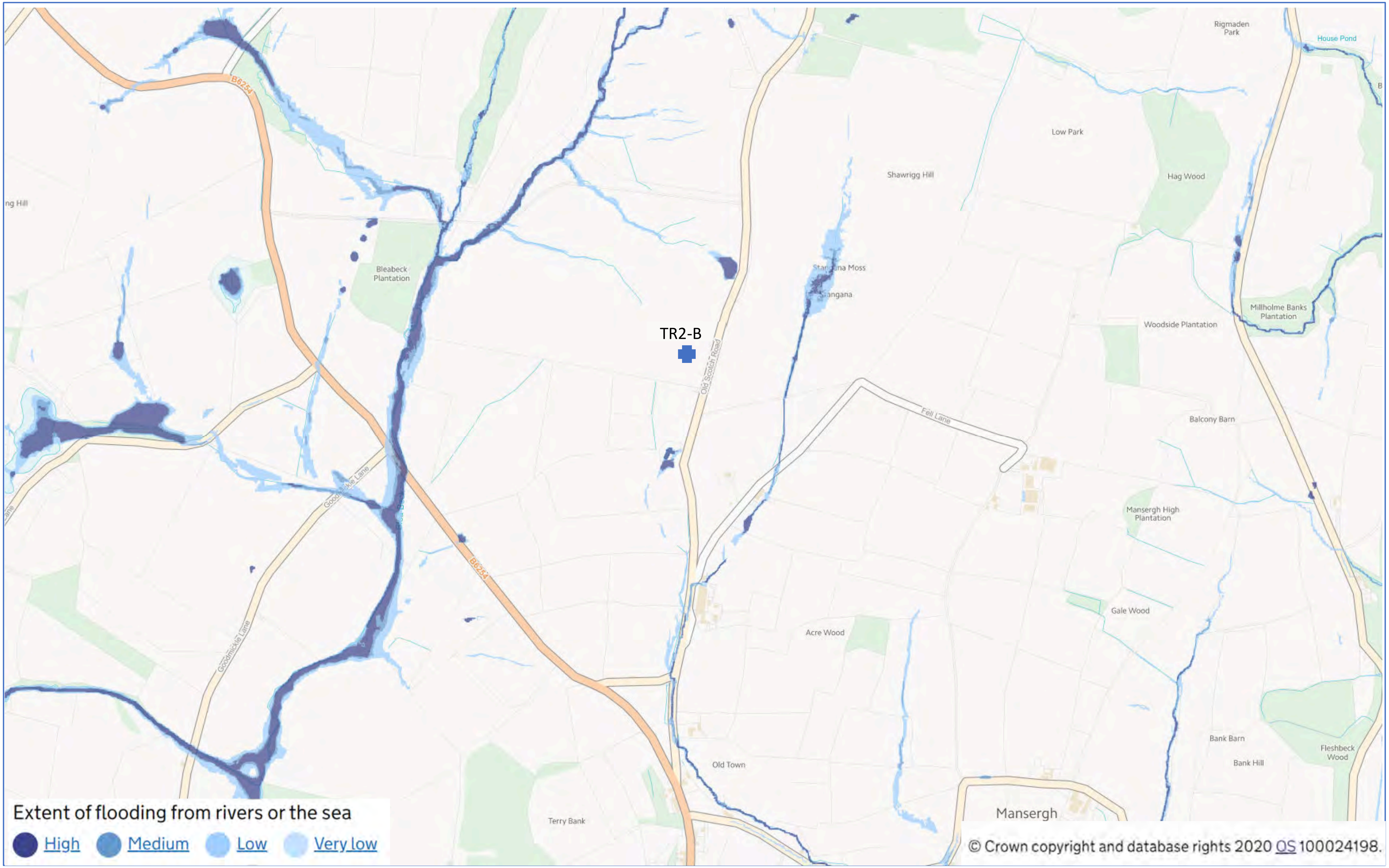
Created
29 Apr 2020 12:31

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR2-B

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR2-B Working Platform
Site location:	LA6 2ER

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	54.24976° N
Longitude:	2.62189° W
Reference:	2331891271
Date:	Apr 29 2020 14:58

Site characteristics

Total site area (ha):	0.73
Significant public open space (ha):	0
Area positively drained (ha):	0.73
Impermeable area (ha):	0.73
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.73
Net impermable area for storage volume design (ha):	0.73
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	2	2
SPR:	0.3	0.3

Hydrological characteristics

	Default	Edited
Rainfall 100 yrs 6 hrs:	--	70
Rainfall 100 yrs 12 hrs:	--	93.24
FEH / FSR conversion factor:	1.11	1.11
SAAR (mm):	1304	1304
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.3	0.3
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	2.75	2.75
Q_{BAR} for net site area (l/s):	2.75	2.75

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5	5
1 in 30 years (l/s):	5	5
1 in 100 year (l/s):	5	5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	426	426
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	426	426

Environment Agency

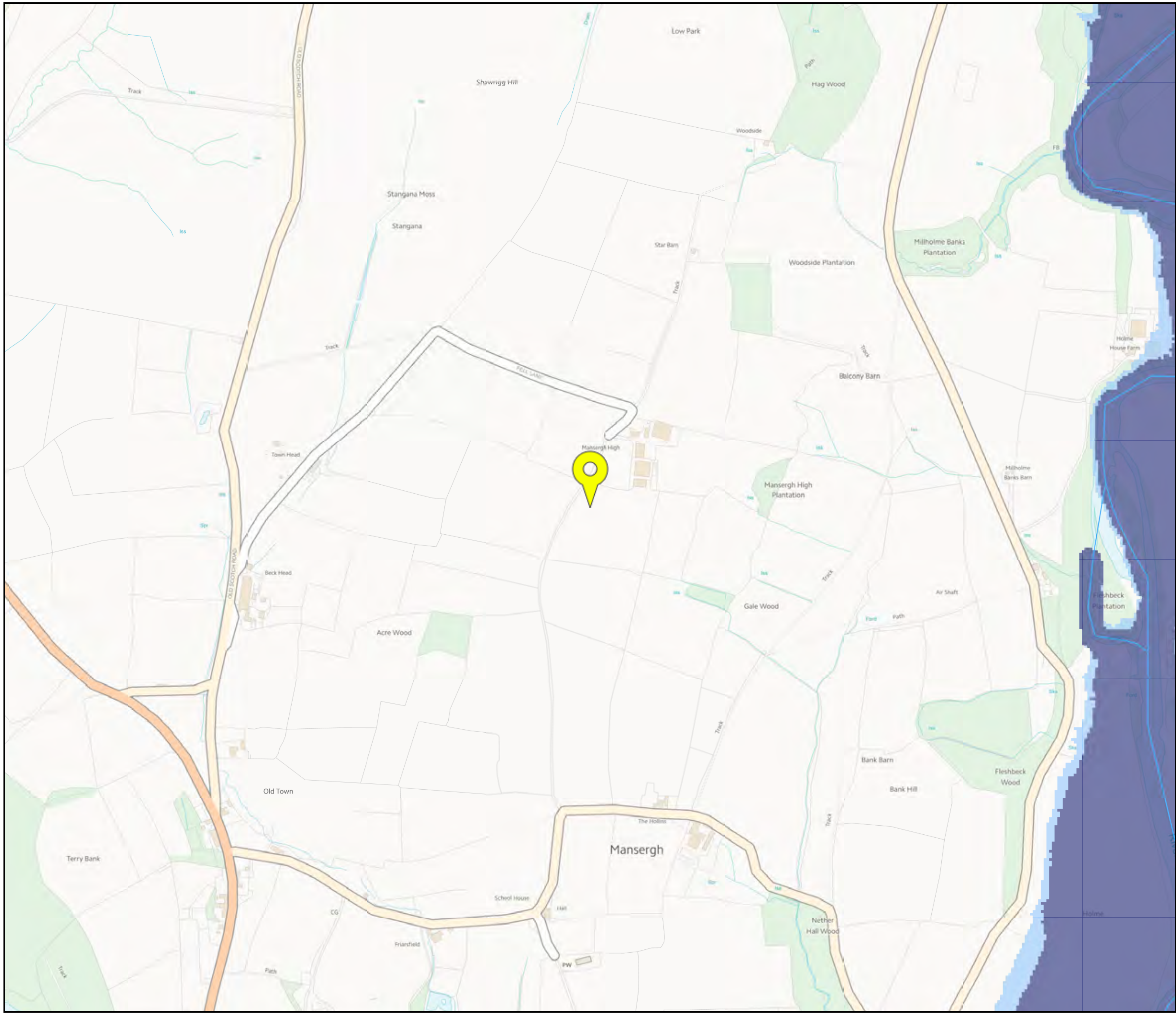
Flood map for planning

Your reference
TR2-B1

Location (easting/northing)
360253/483533

Scale
1:10000

Created
7 May 2020 13:50

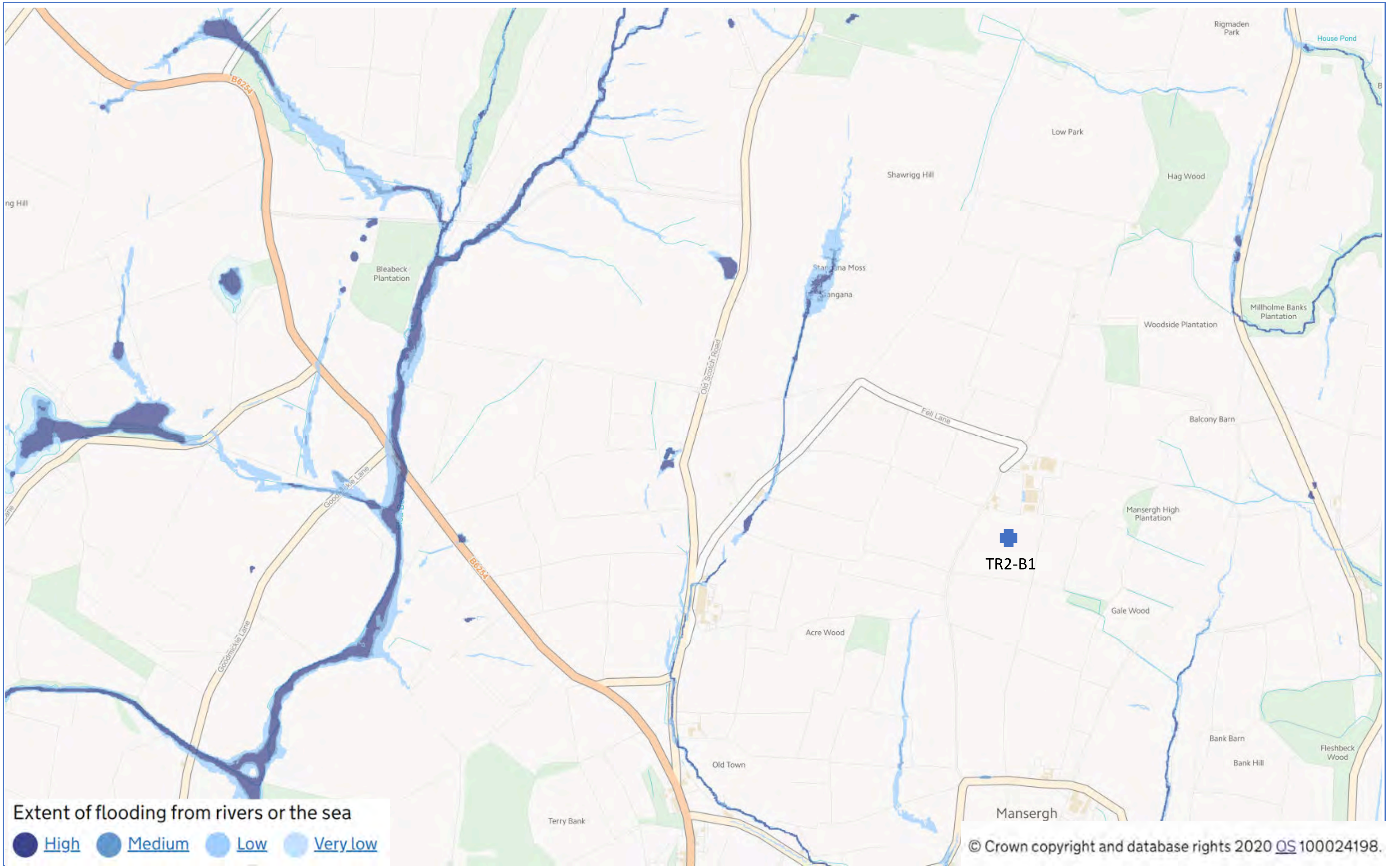


- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR2-B1

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR2-B1
Site location:	LA6 2EW

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	54.24598° N
Longitude:	2.61117° W
Reference:	3667468301
Date:	May 07 2020 15:01

Site characteristics

Total site area (ha):	0.63
Significant public open space (ha):	0
Area positively drained (ha):	0.63
Impermeable area (ha):	0.63
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.63
Net impermable area for storage volume design (ha):	0.63
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	2	2
SPR:	0.3	0.3

Hydrological characteristics

	Default	Edited
Rainfall 100 yrs 6 hrs:	--	70
Rainfall 100 yrs 12 hrs:	--	93.24
FEH / FSR conversion factor:	1.11	1.11
SAAR (mm):	1317	1317
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.3	0.3
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	2.41	2.41
Q_{BAR} for net site area (l/s):	2.41	2.41

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5	5
1 in 30 years (l/s):	5	5
1 in 100 year (l/s):	5	5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	347	347
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	347	347

Environment Agency

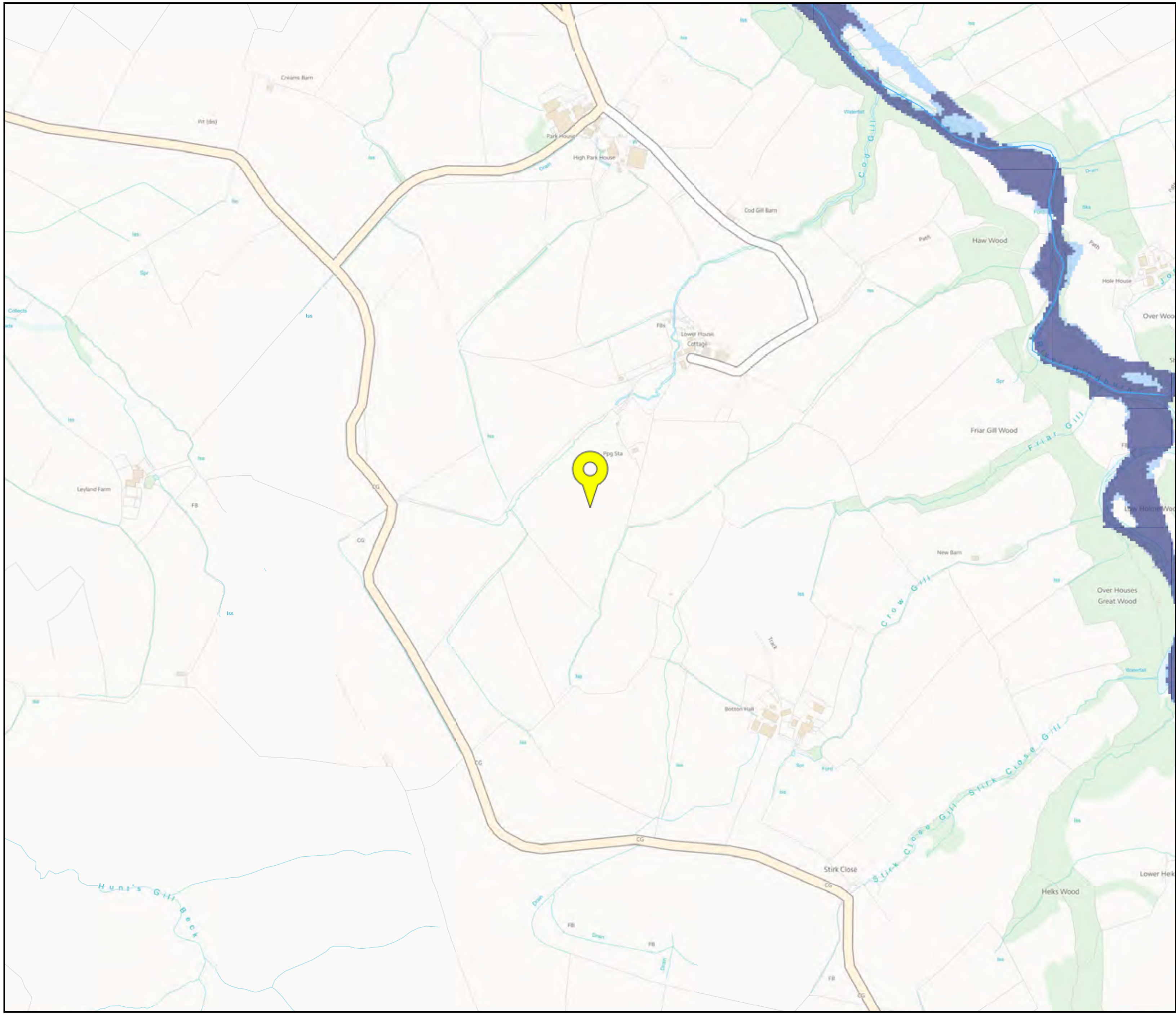
Flood map for planning

Your reference
TR3-A

Location (easting/northing)
363590/465537

Scale
1:10000

Created
7 May 2020 13:52

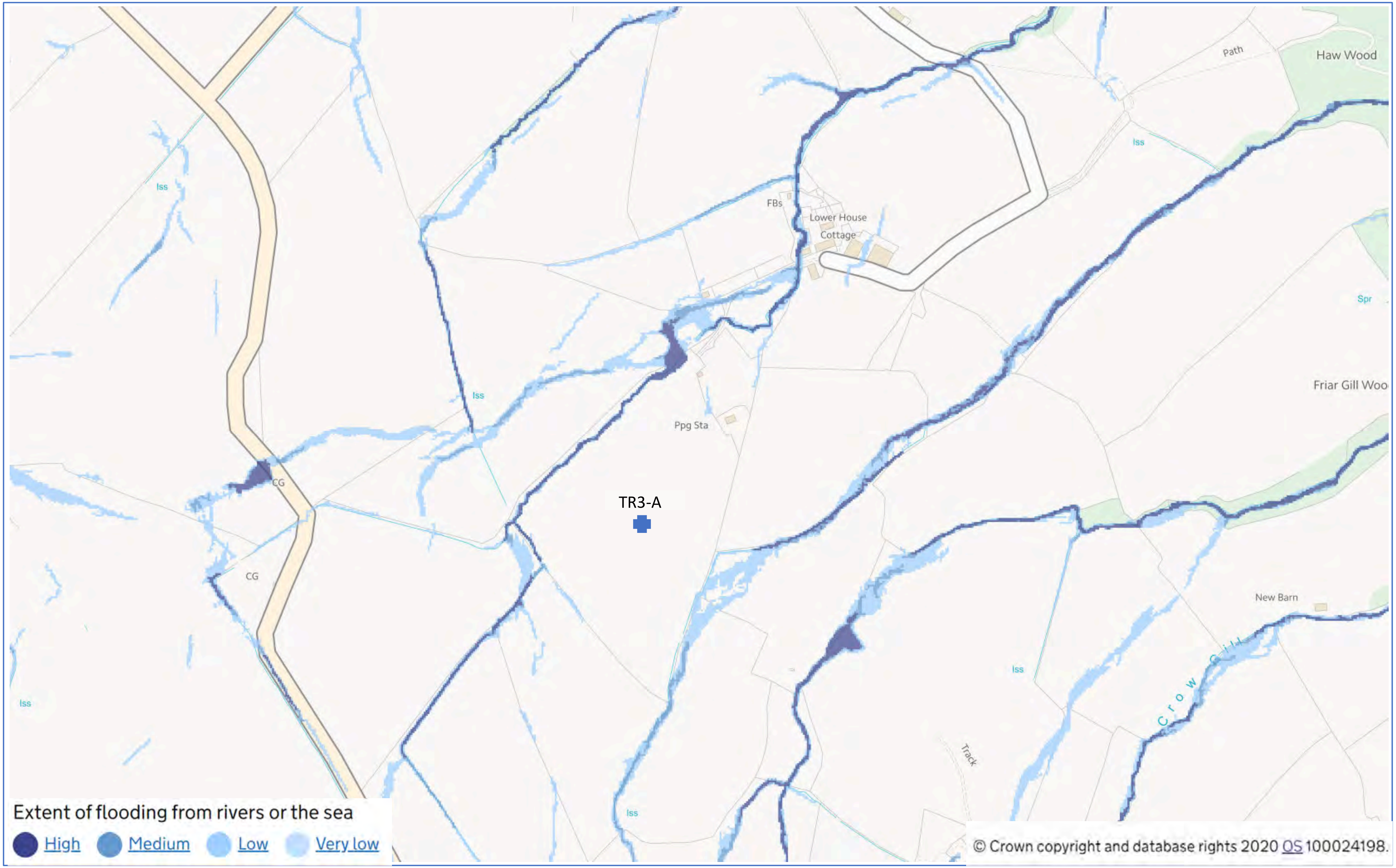


- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR3-A

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR3-A
Site location:	LA2 8QU

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	54.08500° N
Longitude:	2.55708° W
Reference:	4216924200
Date:	Apr 28 2020 12:02

Site characteristics

Total site area (ha):	0.61
Significant public open space (ha):	0
Area positively drained (ha):	0.61
Impermeable area (ha):	0.61
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.61
Net impermable area for storage volume design (ha):	0.61
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	4	4
SPR:	0.47	0.47

Hydrological characteristics

	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	118.45
FEH / FSR conversion factor:	1.15	1.15
SAAR (mm):	1349	1349
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	6.35	6.35
Q_{BAR} for net site area (l/s):	6.35	6.35

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5.5	5.5
1 in 30 years (l/s):	6.3	6.3
1 in 100 year (l/s):	6.3	6.3

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m^3):	481	481
Long term storage 1/100 years (m^3):	0	0
Total storage 1/100 years (m^3):	481	481

Environment Agency

Flood map for planning

Your reference
TR3-C

Location (easting/northing)
368914/450480

Scale
1:10000

Created
7 May 2020 13:55

Selected point

Flood zone 3

Flood zone 3: areas benefitting from flood defences

Flood zone 2

Flood zone 1

Flood defence

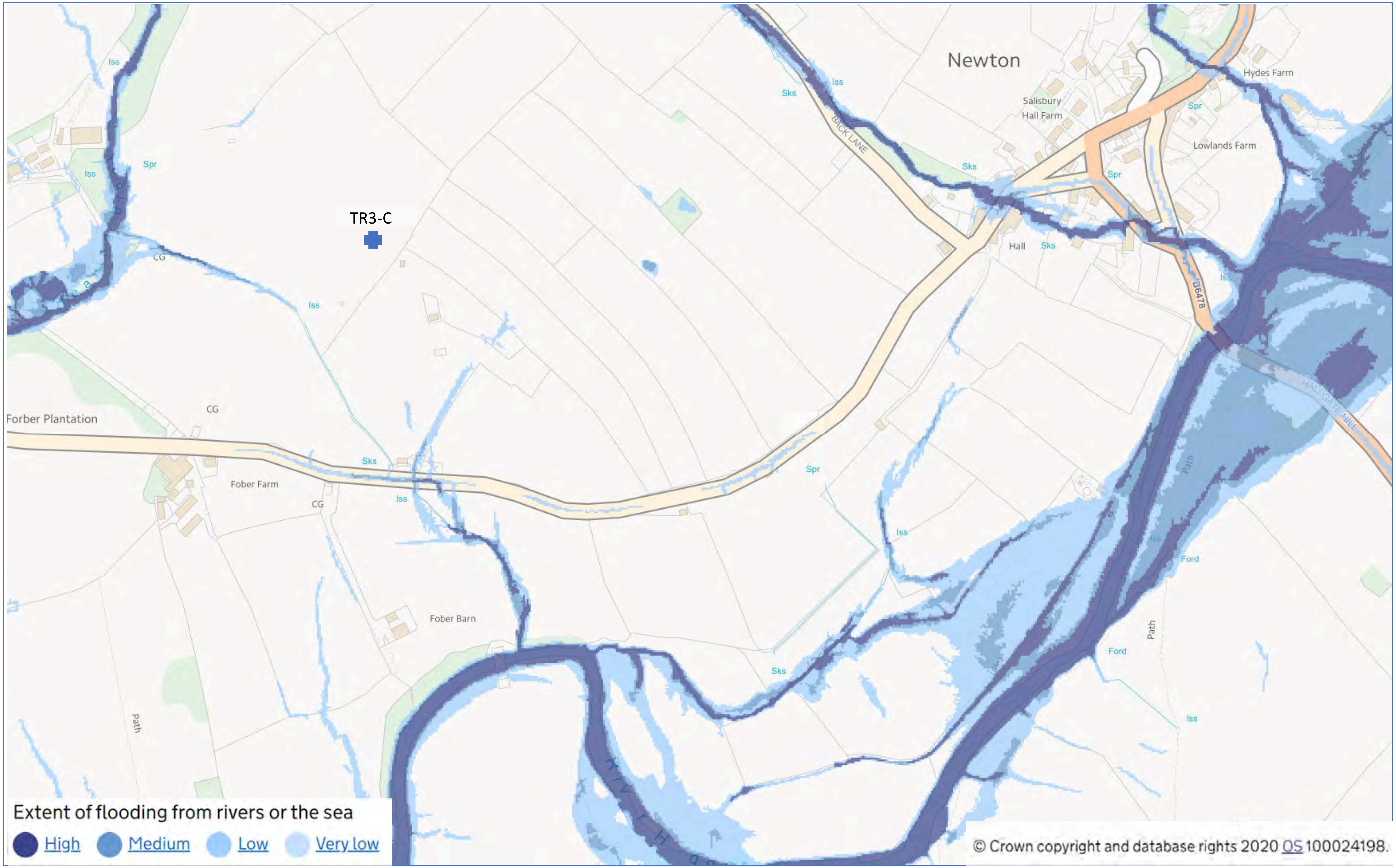
Main river

Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR3-C

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR3-C Portal & Approach road
Site location:	BB7 3ED

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	53.94825° N
Longitude:	2.47474° W
Reference:	1042874444
Date:	Apr 30 2020 18:55

Site characteristics

Total site area (ha):	0.8
Significant public open space (ha):	0
Area positively drained (ha):	0.8
Impermeable area (ha):	0.8
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.8
Net impermable area for storage volume design (ha):	0.8
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	4	4
SPR:	0.47	0.47

Hydrological characteristics

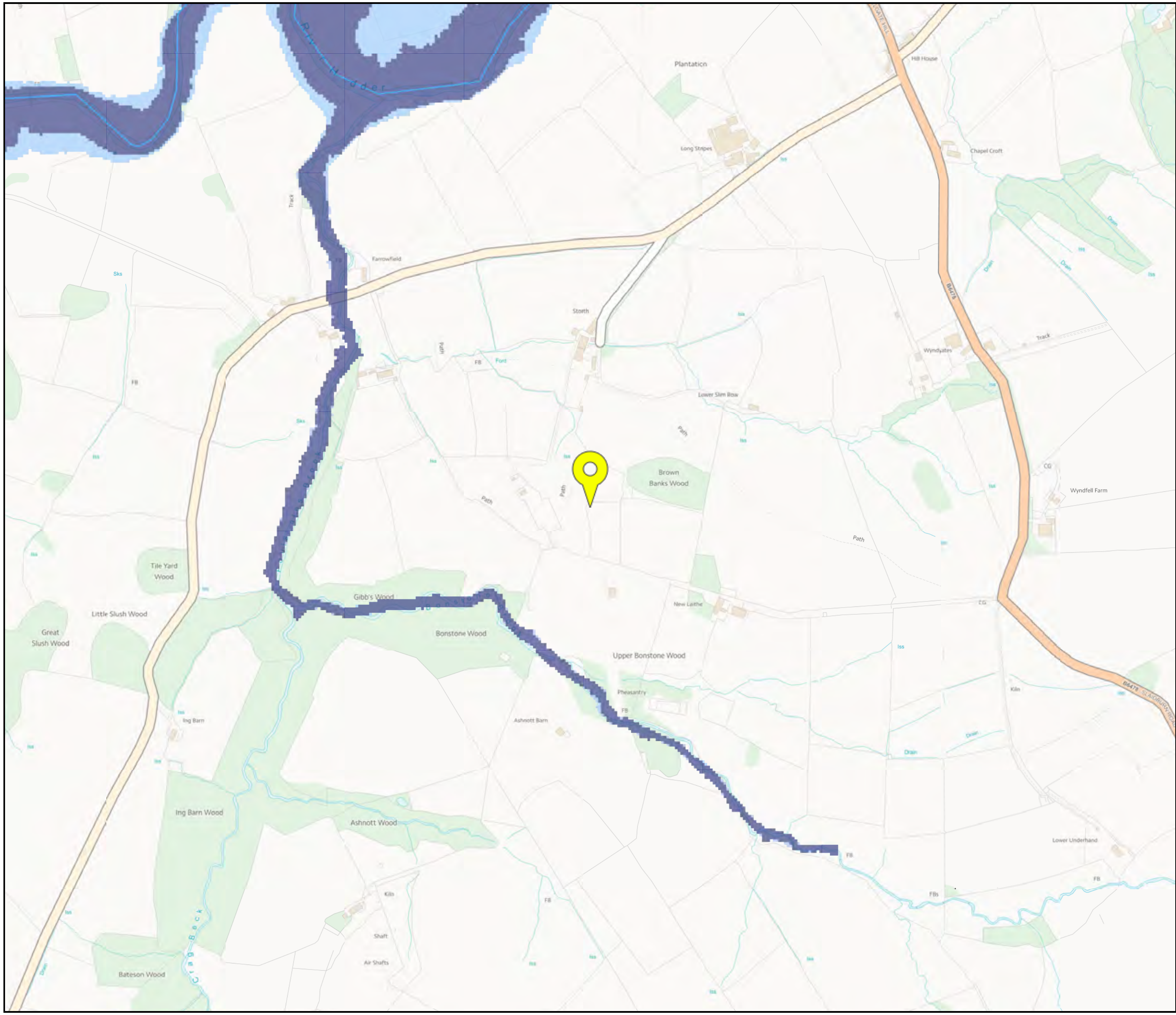
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	118.45
FEH / FSR conversion factor:	1.15	1.15
SAAR (mm):	1535	1535
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	9.68	9.68
Q_{BAR} for net site area (l/s):	9.68	9.68

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	8.4	8.4
1 in 30 years (l/s):	9.7	9.7
1 in 100 year (l/s):	9.7	9.7

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	568	568
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	568	568



Environment Agency

Flood map for planning

Your reference
TR4-A

Location (easting/northing)
369700/448918

Scale
1:10000

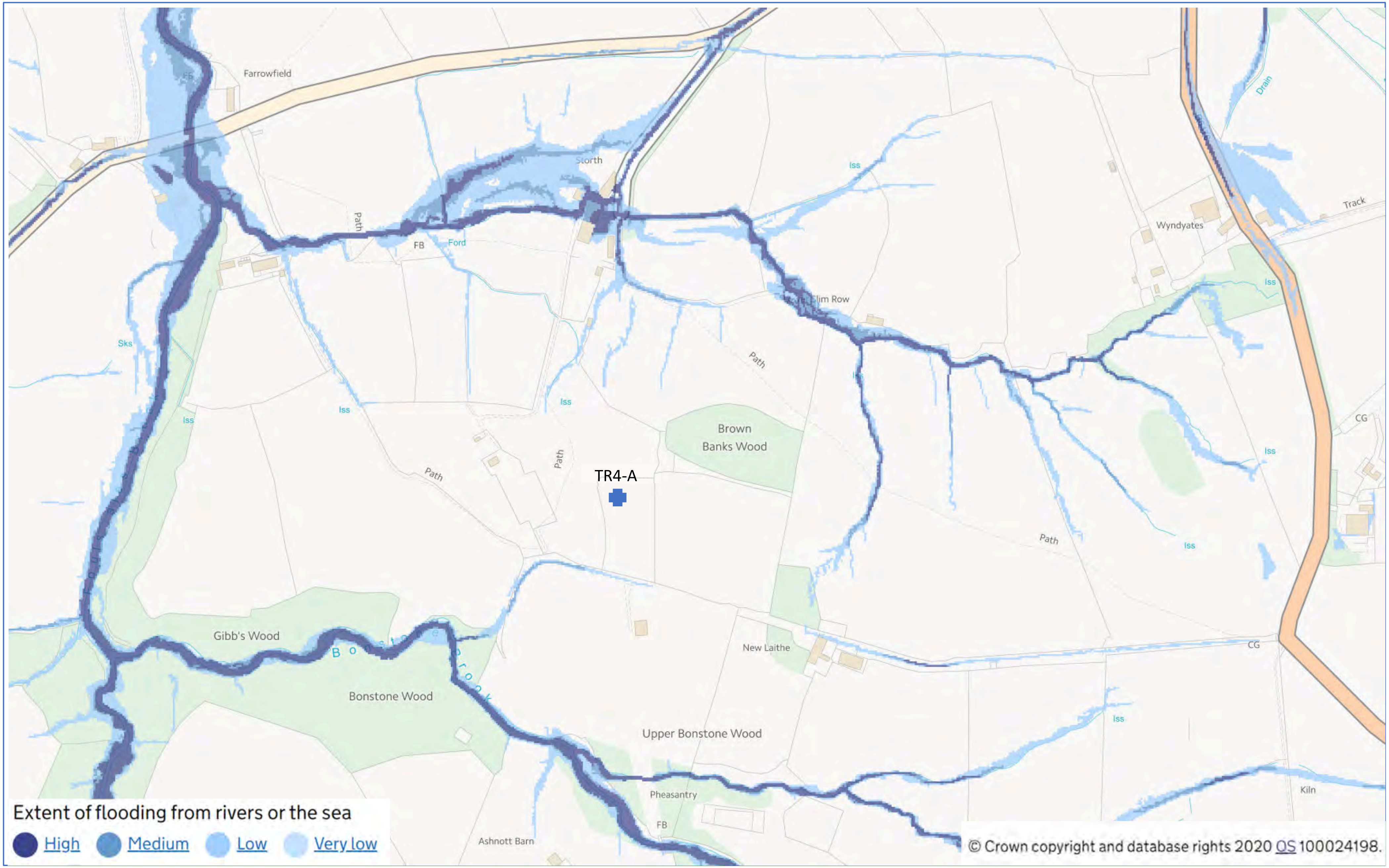
Created
7 May 2020 13:57

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR4-A

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR4-A
Site location:	BB7 3AB

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	53.93698° N
Longitude:	2.46171° W
Reference:	2651495097
Date:	Apr 22 2020 16:08

Site characteristics

Total site area (ha):	0.53
Significant public open space (ha):	0
Area positively drained (ha):	0.53
Impermeable area (ha):	0.53
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.53
Net impermable area for storage volume design (ha):	0.53
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	4	4
SPR:	0.47	0.47

Hydrological characteristics

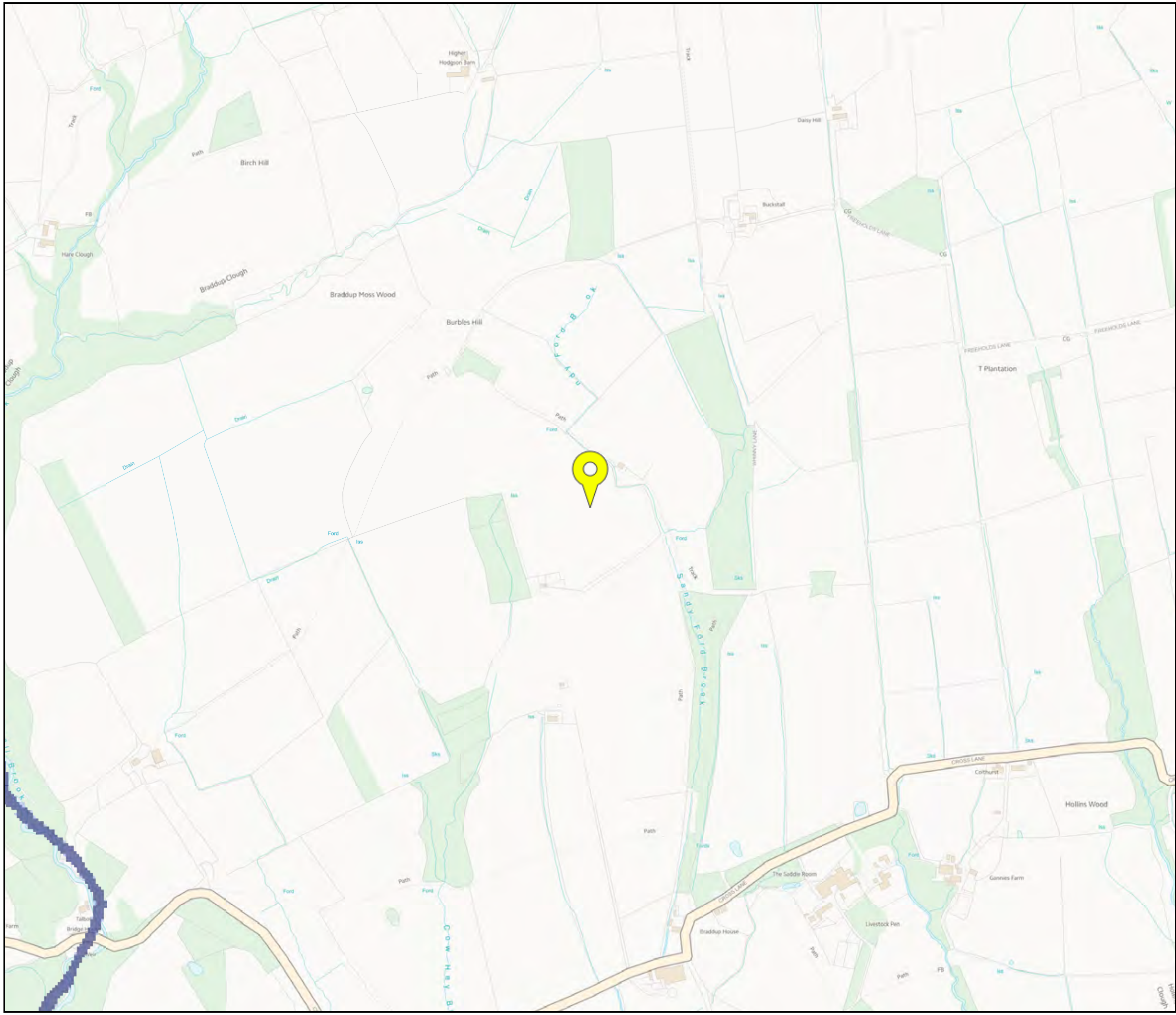
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	114.33
FEH / FSR conversion factor:	1.11	1.11
SAAR (mm):	1484	1484
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	6.16	6.16
Q_{BAR} for net site area (l/s):	6.16	6.16

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5.4	5.4
1 in 30 years (l/s):	6.2	6.2
1 in 100 year (l/s):	6.2	6.2

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	366	366
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	366	366



Environment Agency

Flood map for planning

Your reference
TR4-B

Location (easting/northing)
371012/445010

Scale
1:10000

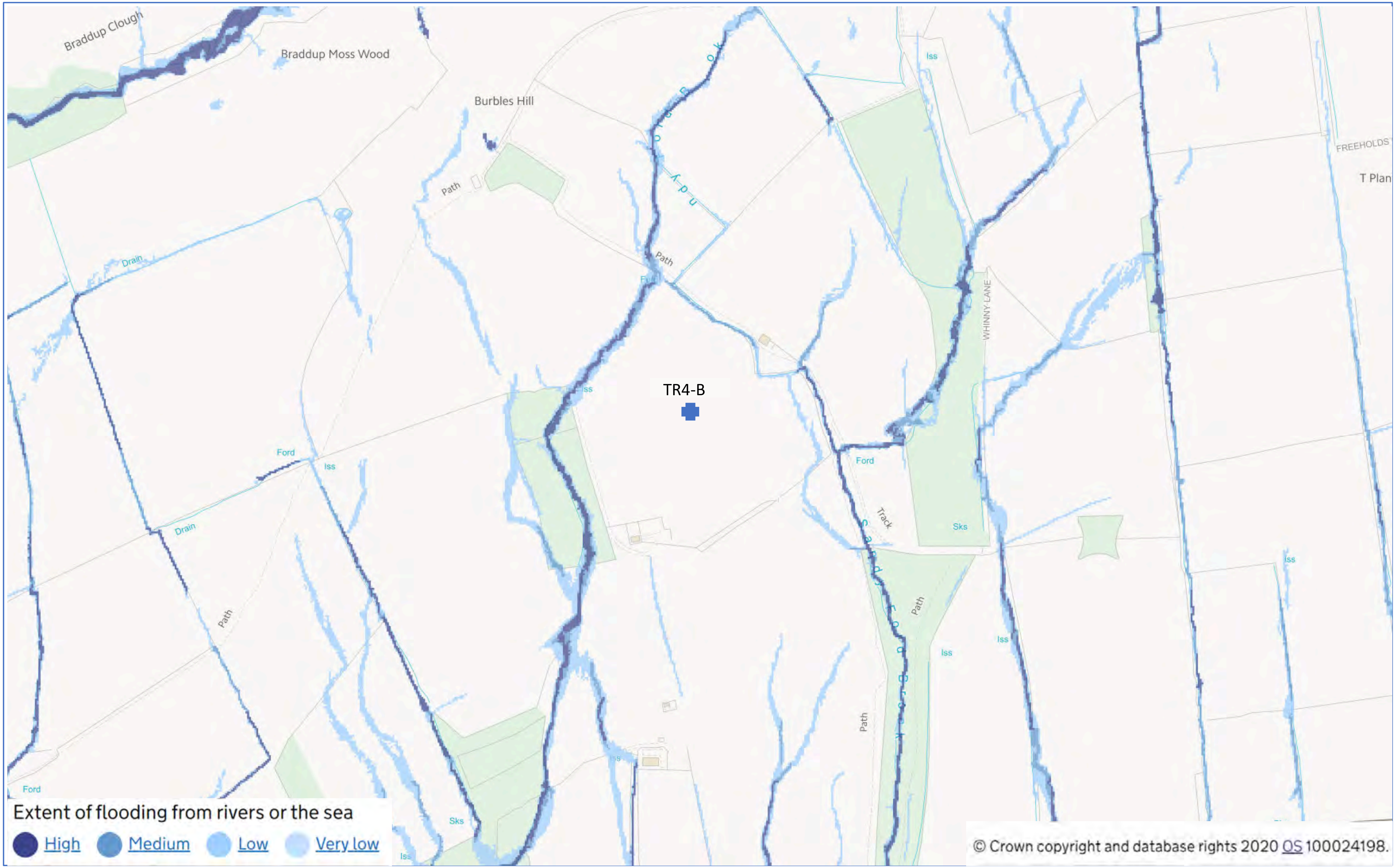
Created
7 May 2020 14:00

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR4-B

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR4-B
Site location:	BB7 3JH

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	53.90003° N
Longitude:	2.44297° W
Reference:	2411790616
Date:	Apr 22 2020 17:51

Site characteristics

Total site area (ha):	0.97
Significant public open space (ha):	0
Area positively drained (ha):	0.97
Impermeable area (ha):	0.97
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.97
Net impermable area for storage volume design (ha):	0.97
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	4	4
SPR:	0.47	0.47

Hydrological characteristics

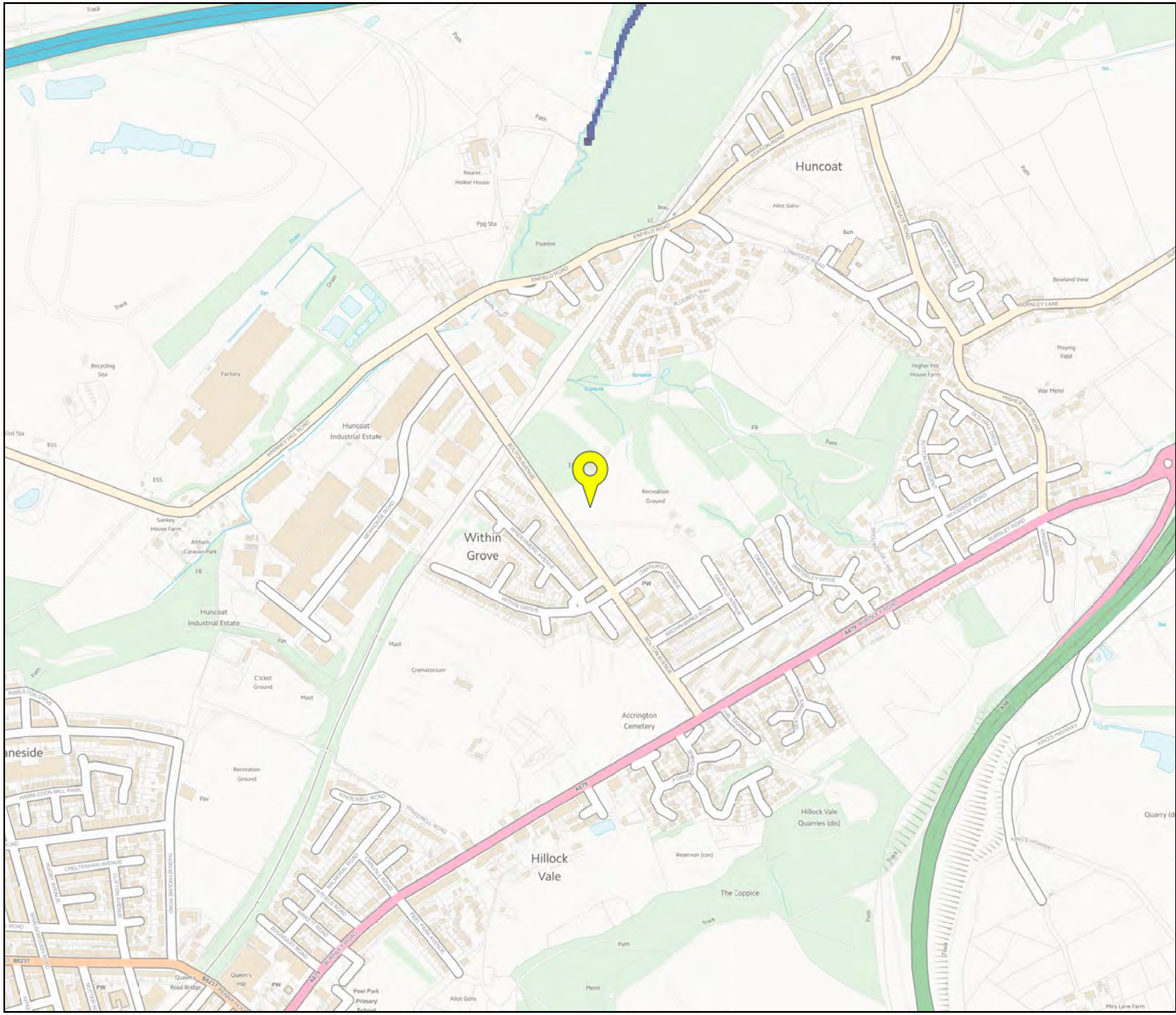
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	112.27
FEH / FSR conversion factor:	1.09	1.09
SAAR (mm):	1341	1341
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	10.02	10.02
Q_{BAR} for net site area (l/s):	10.02	10.02

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	8.7	8.7
1 in 30 years (l/s):	10	10
1 in 100 year (l/s):	10	10

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	706	706
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	706	706



Environment Agency

Flood map for planning

Your reference
TR5-A

Location (easting/northing)
377077/430167

Scale
1:10000

Created
7 May 2020 14:18

Selected point

Flood zone 3

Flood zone 3: areas benefitting from flood defences

Flood zone 2

Flood zone 1

Flood defence

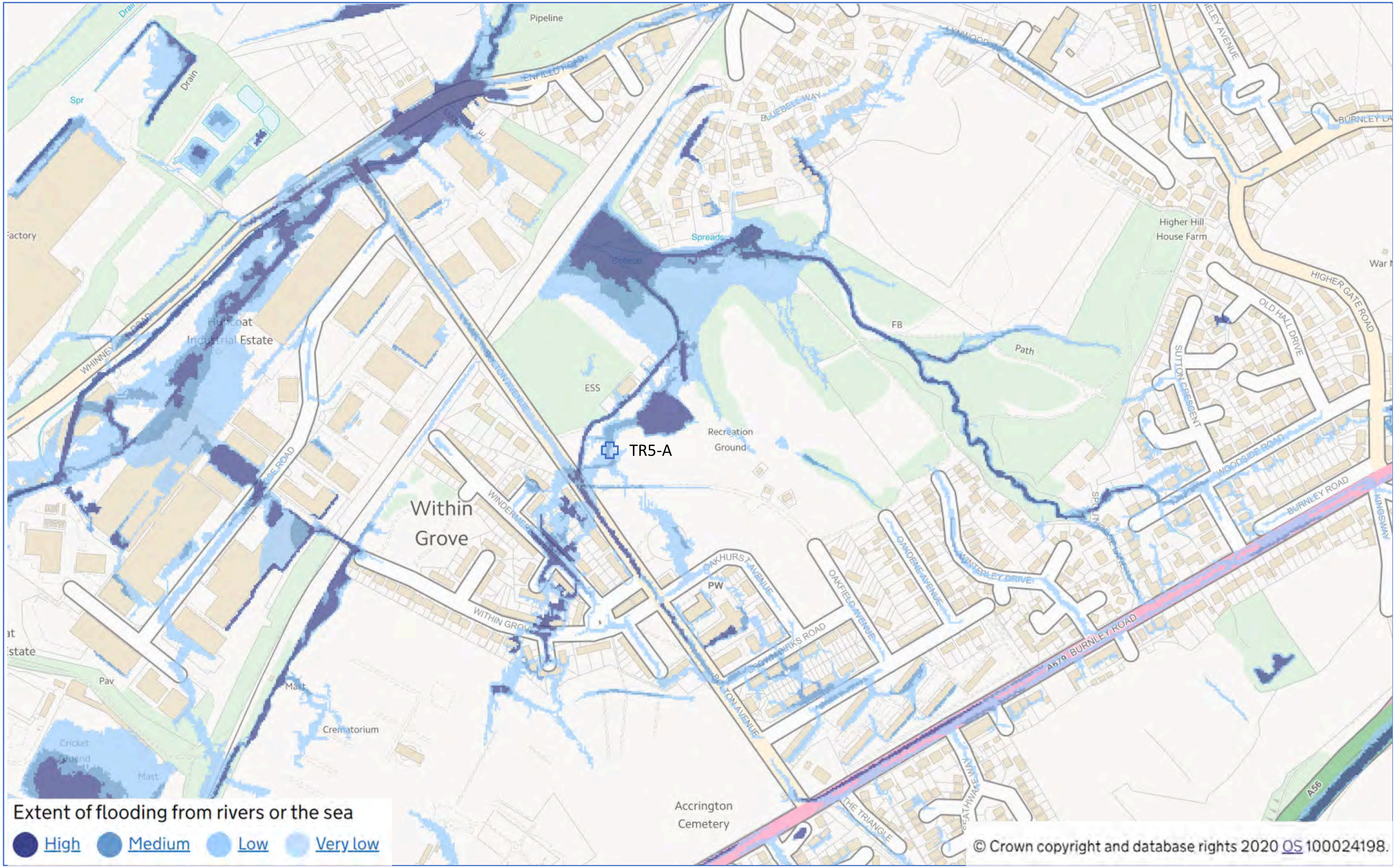
Main river

Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR5-A

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR5-A
Site location:	BB5 6HT

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	53.76744° N
Longitude:	2.34914° W
Reference:	1935695554
Date:	Apr 23 2020 18:33

Site characteristics

Total site area (ha):	0.5
Significant public open space (ha):	0
Area positively drained (ha):	0.5
Impermeable area (ha):	0.5
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.5
Net impermable area for storage volume design (ha):	0.5
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	4	4
SPR:	0.47	0.47

Hydrological characteristics

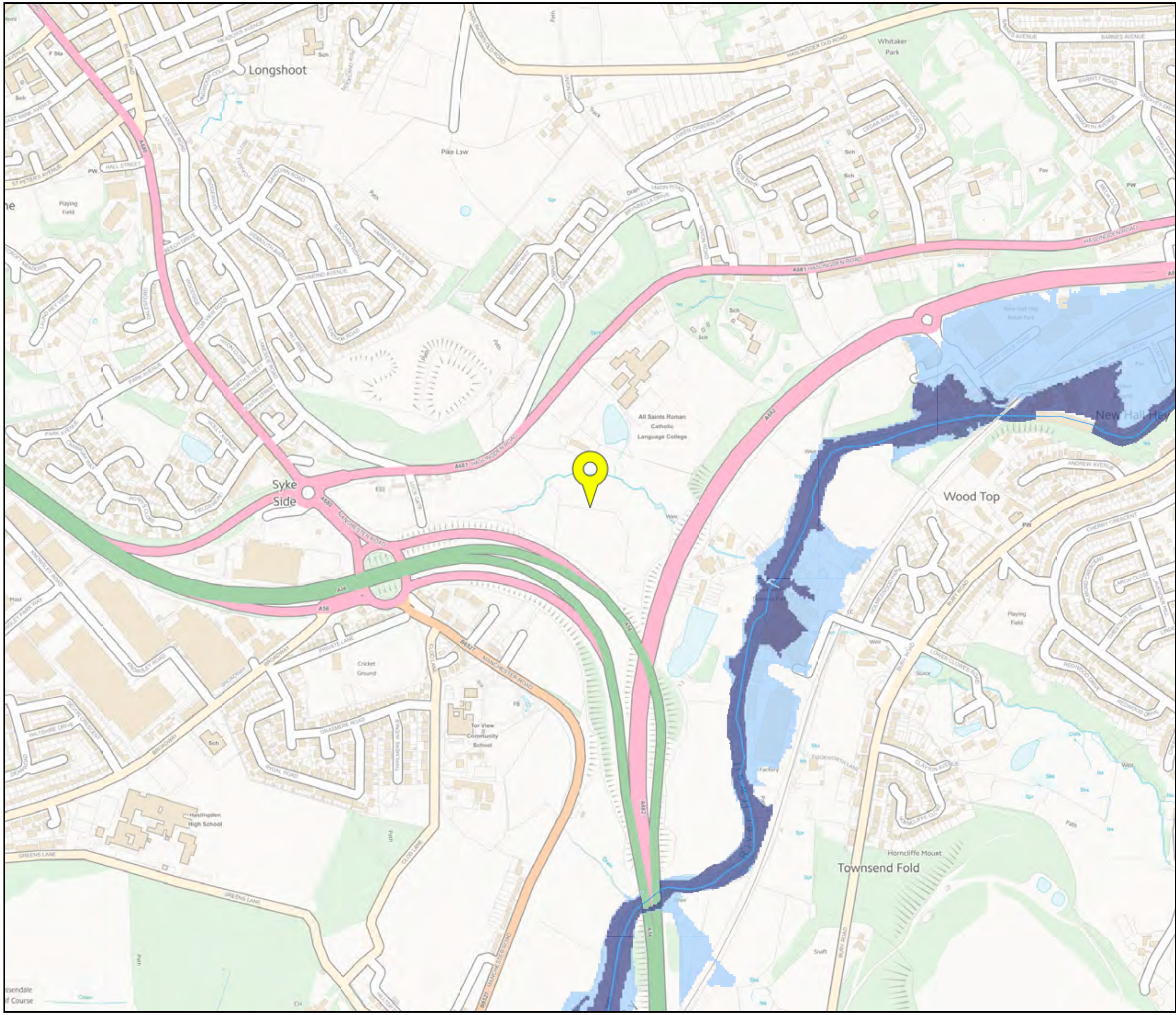
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	70
Rainfall 100 yrs 12 hrs:	--	92.4
FEH / FSR conversion factor:	1.1	1.1
SAAR (mm):	1180	1180
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.3	0.3
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	4.45	4.45
Q_{BAR} for net site area (l/s):	4.45	4.45

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5	5
1 in 30 years (l/s):	5	5
1 in 100 year (l/s):	5	5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	284	284
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	284	284



Environment Agency

Flood map for planning

Your reference
TR5-I

Location (easting/northing)
379769/422099

Scale
1:10000

Created
6 Apr 2020 18:18

Selected point

Flood zone 3

Flood zone 3: areas benefitting from flood defences

Flood zone 2

Flood zone 1

Flood defence

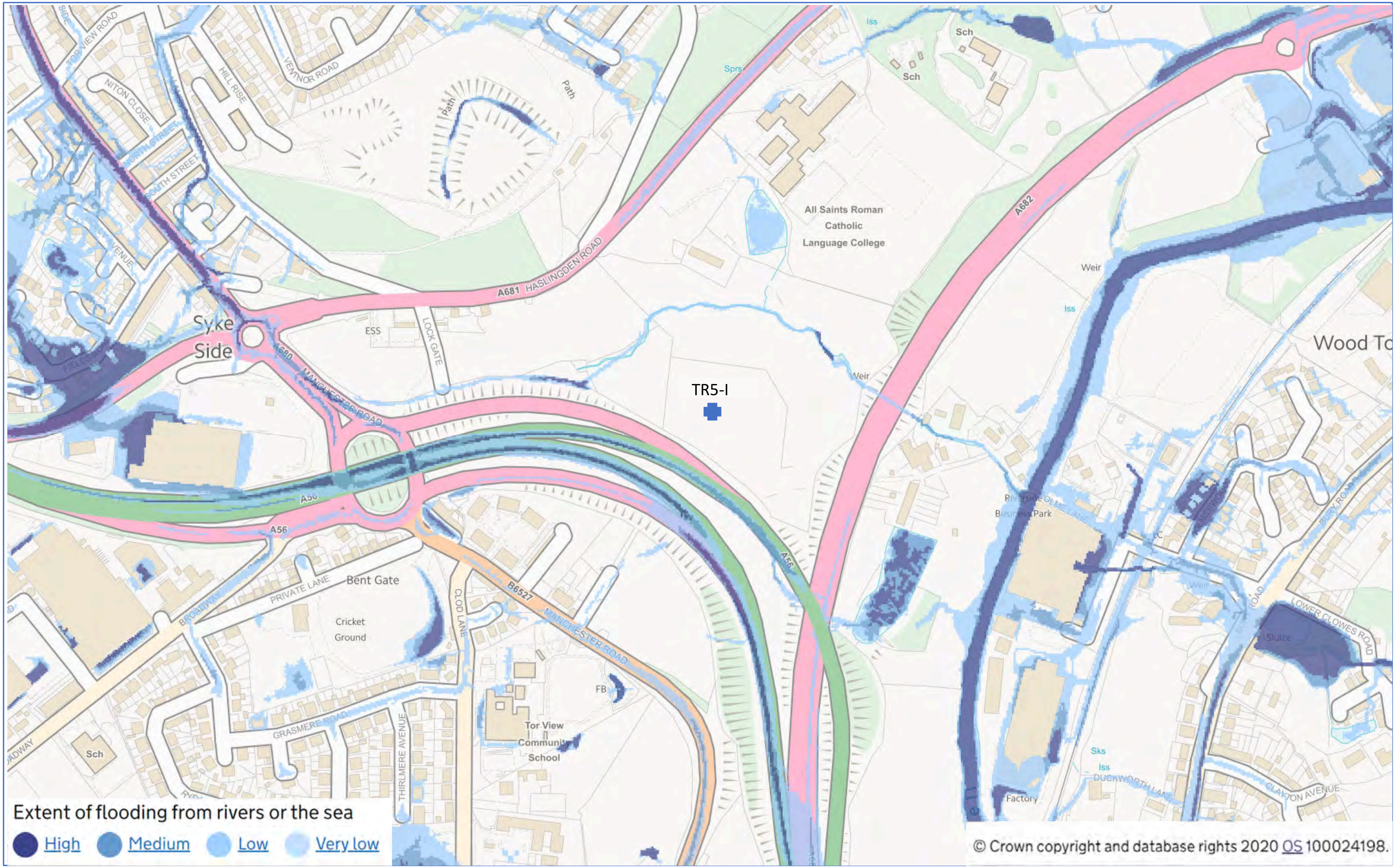
Main river

Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR5-I

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

HR Wallingford — Working with water

Calculated by:	Michael Lloyd
Site name:	TR5-I Working platform
Site location:	BB4 6QG

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	53.69436° N
Longitude:	2.30712° W
Reference:	2921664057
Date:	May 07 2020 14:34

Site characteristics

Total site area (ha):	1.7
Significant public open space (ha):	0
Area positively drained (ha):	1.7
Impermeable area (ha):	1.7
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	1.7
Net impermable area for storage volume design (ha):	1.7
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	5	5
SPR:	0.53	0.53

Hydrological characteristics

	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	115.36
FEH / FSR conversion factor:	1.12	1.12
SAAR (mm):	1361	1361
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	23.19	23.19
Q_{BAR} for net site area (l/s):	23.19	23.19

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	20.2	20.2
1 in 30 years (l/s):	23.2	23.2
1 in 100 year (l/s):	23.2	23.2

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m^3):	1055	1055
Long term storage 1/100 years (m^3):	0	0
Total storage 1/100 years (m^3):	1055	1055

Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Michael Lloyd
Site name:	TR5-I Offices/welfare/parking & Access road
Site location:	BB4 6QG

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance “Rainfall runoff management for developments”, SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	53.69436° N
Longitude:	2.30712° W
Reference:	2292463481
Date:	May 07 2020 14:36

Site characteristics

Total site area (ha):	0.7
Significant public open space (ha):	0
Area positively drained (ha):	0.7
Impermeable area (ha):	0.7
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.7
Net impermable area for storage volume design (ha):	0.7
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	5	5
SPR:	0.53	0.53

Hydrological characteristics

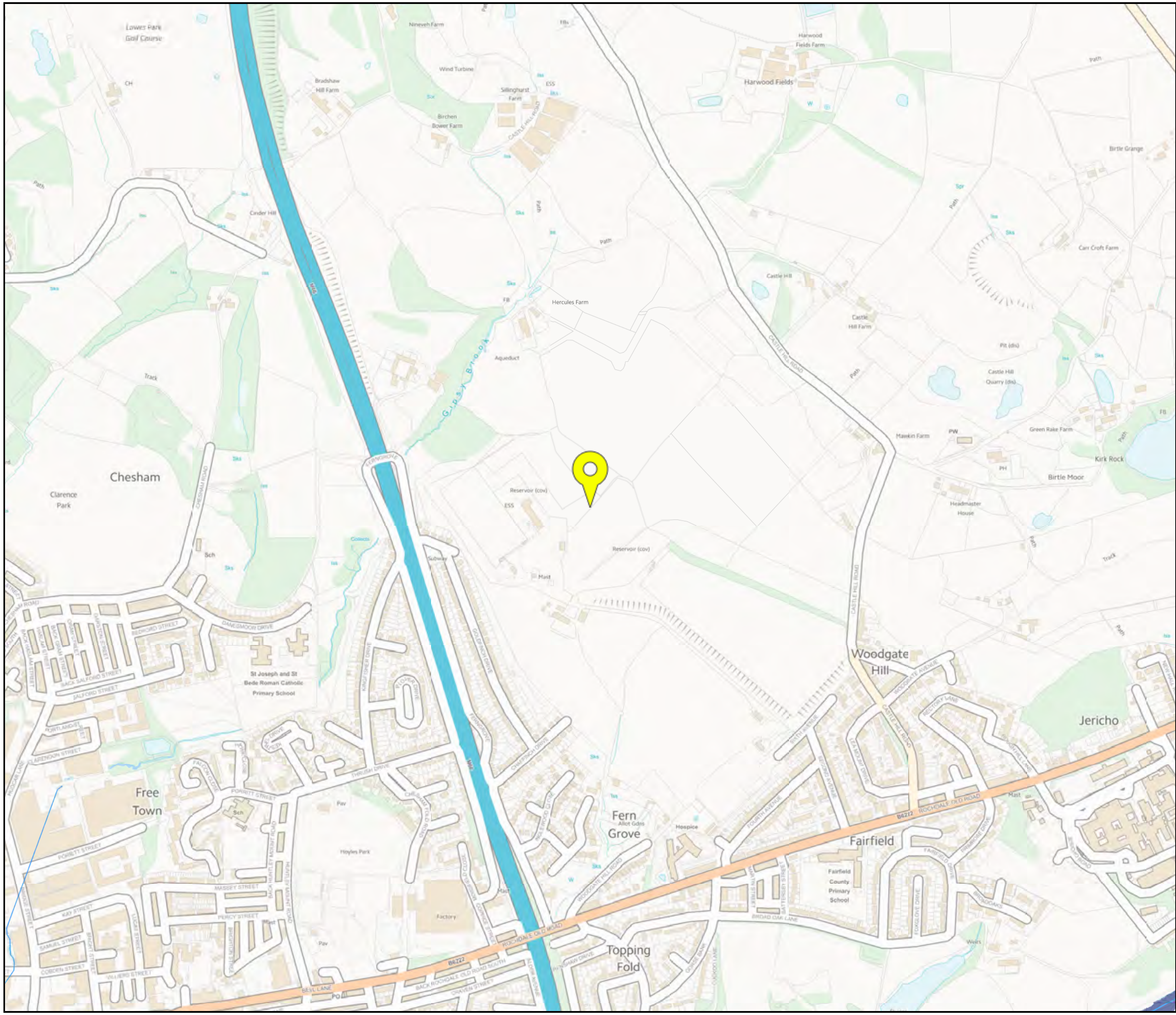
	Default	Edited
Rainfall 100 yrs 6 hrs:	--	82
Rainfall 100 yrs 12 hrs:	--	115.36
FEH / FSR conversion factor:	1.12	1.12
SAAR (mm):	1361	1361
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.2	0.2
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	9.55	9.55
Q_{BAR} for net site area (l/s):	9.55	9.55

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	8.3	8.3
1 in 30 years (l/s):	9.5	9.5
1 in 100 year (l/s):	9.5	9.5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m^3):	435	435
Long term storage 1/100 years (m^3):	0	0
Total storage 1/100 years (m^3):	435	435



Environment Agency

Flood map for planning

Your reference
TR6-G

Location (easting/northing)
382229/412158

Scale
1:10000

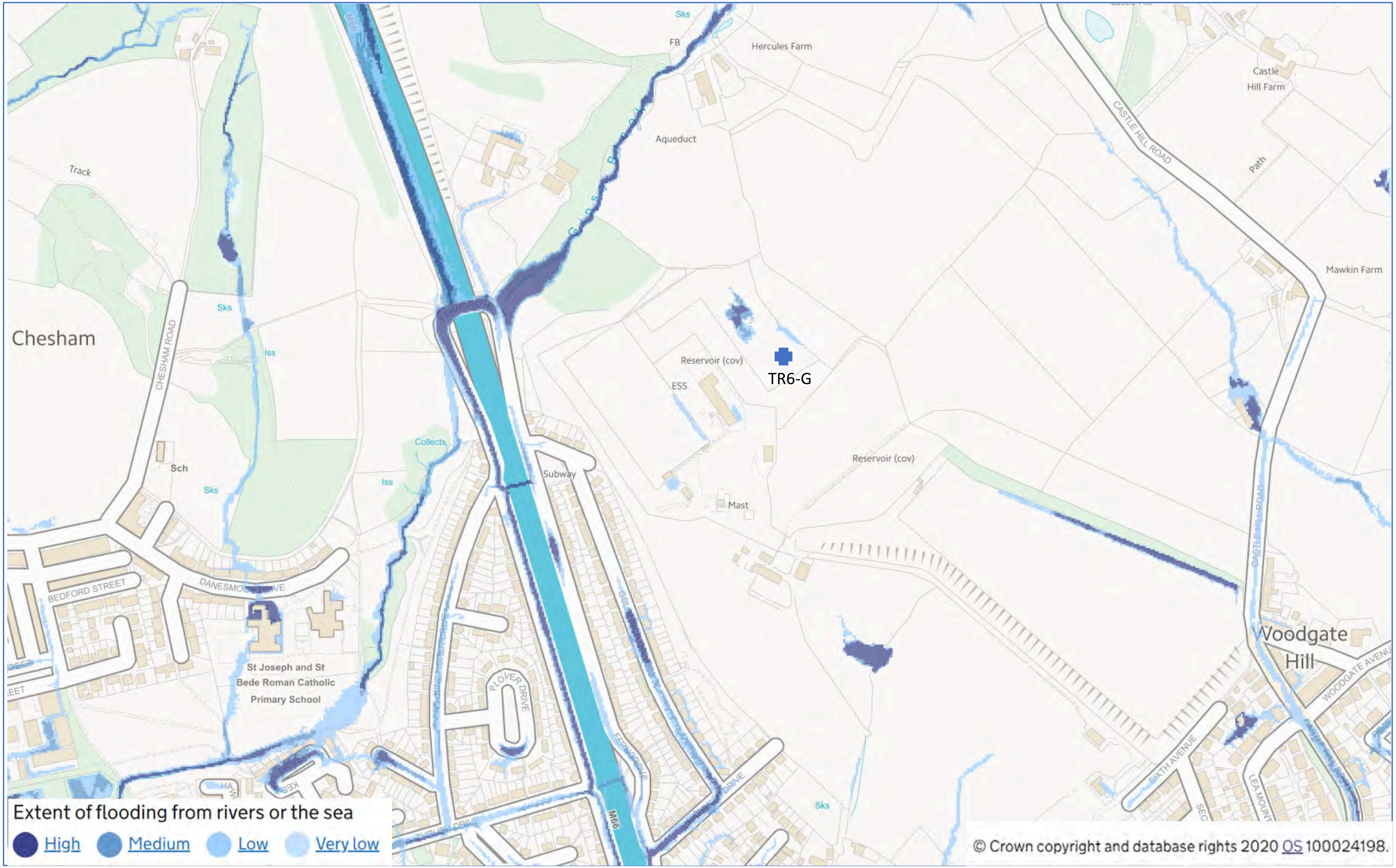
Created
1 May 2020 18:22

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 100 200 300m

Long Term Flood Risk Map – TR6-G

The results shown below are an indicator of the area's flood risk, particularly the likelihood of surface water flooding.



Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

HR Wallingford — Working with water

Calculated by:	Michael Lloyd
Site name:	TR6-G
Site location:	BL9 7LE

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	53.60590° N
Longitude:	2.27131° W
Reference:	1709637230
Date:	Apr 22 2020 21:38

Site characteristics

Total site area (ha):	0.5
Significant public open space (ha):	0
Area positively drained (ha):	0.5
Impermeable area (ha):	0.5
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.5
Net impermable area for storage volume design (ha):	0.5
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.0
Urban creep allowance factor:	1.0
Volume control approach	Flow control to max of 2 l/s/ha or Qbar
Interception rainfall depth (mm):	0
Minimum flow rate (l/s):	5

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	5	5
SPR:	0.53	0.53

Hydrological characteristics

	Default	Edited
Rainfall 100 yrs 6 hrs:	--	70
Rainfall 100 yrs 12 hrs:	--	93.24
FEH / FSR conversion factor:	1.11	1.11
SAAR (mm):	1126	1126
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.3	0.3
Hydological region:	10	10
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 10 year:	1.38	1.38
Growth curve factor 30 year:	1.7	1.7
Growth curve factor 100 years:	2.08	2.08
Q_{BAR} for total site area (l/s):	5.46	5.46
Q_{BAR} for net site area (l/s):	5.46	5.46

Site discharge rates

	Default	Edited
1 in 1 year (l/s):	5	5
1 in 30 years (l/s):	5.5	5.5
1 in 100 year (l/s):	5.5	5.5

Estimated storage volumes

	Default	Edited
Attenuation storage 1/100 years (m³):	264	264
Long term storage 1/100 years (m³):	0	0
Total storage 1/100 years (m³):	264	264