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ENVIRONMENT

Burbury Investments Limited
Ellesmere Canalside Development
Shropshire
Flood Risk Assessment

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P01	14/10/22	S0	Draft Issue – prepared before receipt of final layout and development description.	RG	MB	CT
P02	20/04/23	S2	General update following receipt of layout and development description	RG	MB	RG

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APPENDICES

1. INTRODUCTION

1.1 This Flood Risk Assessment (FRA) has been prepared in accordance with the requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance. The FRA has been produced on behalf of Burbury Investments Limited in respect of a planning application on land located to the south of Ellesmere. The planning application includes a new Link Road through the site, and reprofiling of ground levels to form future development parcels and floodplain storage. These elements will precede and facilitate a future residential-led mixed-use development of the site.

1.2 The site was allocated for development in December 2015 within the Shropshire Council Site Allocations and Management of Development (SAMDev) Plan, reference ELL003a (residential) and ELL003b (leisure and tourism).

1.3 Outline planning permission was originally granted on the site in December 2016 (ref: 14/04047/OUT) for a mixed-use development consisting of a new link road, residential housing, a hotel, boating marina, leisure complex, pub/restaurant, holiday cabins and touring caravans with associated infrastructure and access.

1.4 The previous outline planning permission was supported by an FRA prepared by BWB Consulting in May 2014. This quantified the existing flood risk to the site through the preparation of a site-specific hydraulic model of the local watercourses and identified a flood risk management scheme which included de-culverting a stretch of watercourse, the raising of development parcels out of the floodplain, and the redistribution of the floodplain within formalised storage areas throughout the site.

1.5 This FRA is intended to support a new planning application for the enabling earthworks and link road, which includes the extension of the development area to the west of the Newnes Brook and south of Scotland Street (A495). However, for completeness, the report appraises flood risk to the future completed development.

1.6 The level of detail included is commensurate and subject to the nature of the proposals at the planning stage. Summary information is included as Table 1.1.

Table 1.1: Site Summary

Site Name	Ellesmere Canalside Development
Location	Ellesmere, Shropshire, SY12 0BY
NGR (approx.)	SJ393341 (339300, 334107)
Application Site Area (ha)	32.7 (approx.)
Development Type	Mixed-use
Flood Zone Classification	Mixed - Flood Zone 3, 2 and 1

NPPF Vulnerability	Less Vulnerable: Commercial More Vulnerable: Residential, hotel, residential extra care, short term caravan site Essential Infrastructure: Link Road Water compatible: Floodplain Storage, Landscaping
Anticipated Development Lifetime	100+ years
Environment Agency Office	Midlands West
Lead Local Flood Authority	Shropshire County Council
Local Planning Authority	Shropshire County Council

Sources of Data

i. BWB Consulting hydraulic model of the Tetchill and Newnes Brooks (2022) – ref: EMM-BWB-ZZ-XX-RP-YE-0003_HMR – Appendix 2

ii. Topographical Survey – Appendix 4 of Appendix 2

iii. OS Explorer Series mapping

iv. Environment Agency Risk of Flooding from Surface Water Data

v. Shropshire Strategic Flood Risk Assessment

vi. Shropshire Preliminary Flood Risk Assessment

vii. Shropshire Council Site Allocations and Management of Development (SAMDev) Plan

viii. Site visit undertaken by BWB Consulting Ltd

ix. Ground Investigations undertaken by BWB Consulting (BMW2025/01/V2 & EEM-BWB-ZZ-XX-YE-RP-0001-GI)

x. Severn Trent Sewer Records

xi. British Geological Survey Drift & Geology Maps

xii. Canal and River Trust Consultation and Asset Data

xiii. Environment Agency 1m DTM LiDAR

xiv. Indicative Masterplan prepared by Roberts Limerick (5614-PL500S) - Appendix 4

xv. Strategic ground model and development levels plan/model prepared by SGI Consulting Engineers – Appendix 4

Existing Site

1.7 The site is located on the southern fringe of Ellesmere, Shropshire as illustrated within Figure 1.1. To the north is a recent residential development centralised around Tetchill Brook Road along with the Lakelands Academy and Scotland Street (A495). To the south and east is the Llangollen Branch of the Shropshire Union Canal. Grassland/pasture abuts the site to the west.

1.8 The application site is currently greenfield and is used as pasture. Photographs illustrating the condition of the site are provided within Figure 1.2 to Figure 1.7.

Figure 1.1: Site Location

Figure 1.2: View of the East of the Site

Figure 1.3: View of the Southern Boundary of the Site


Figure 1.4: View of the Centre of the Site


Figure 1.5: View of the West of the Site

Figure 1.6: View of the Tetchill brook Corridor in the East of the Site

Figure 1.7: View of the Newnes Brook Corridor in the West of the Site

1.9 The Tetchill Brook is an ordinary watercourse fed from 'The Mere', a large lake located to the east of Ellesmere. It is culverted from the lake and through the town within the public surface water sewer network. The culvert through the town is comprised of a mix of 450mm diameter pipes and a stone arch culvert.

1.10 The brook enters the site from beneath the canal on the eastern boundary and flows within a short open reach. After 450m of open channel, the brook re-enters culvert where it remains until outfalling 1.2km further downstream. This outfall location is 470m downstream of the site's western boundary. The culvert here is of a stone arch construction. The culvert receives additional inflows from canal overflow drains and land drainage. The Tetchill Brook culvert receives an inflow from the Newnes Brook 125m downstream of the site, at which point the watercourse is reclassified as Main River.

1.11 At the outlet from the 1.2km culverted reach, the Tetchill Brook is joined by a tributary watercourse draining land to the south-west of Ellesmere. The Tetchill Brook then continues to flow in a south-easterly direction and passes beneath the Shropshire Union Canal (Llangollen Branch) for a second time. Downstream of the canal, the brook flows in open channel through farmland in an easterly and then southerly direction towards the village of Tetchill.

1.12 The Newnes Brook is a Main River which flows from the north-west of Ellesmere in a southerly direction to the west of the town. The watercourse flows between the Ellesmere Business Park and a residential estate, and then passes beneath the A495 (Scotland Street) and along the site boundary within a 150m long culvert that reduces from a 1500mm diameter pipe to a 1050mm diameter pipe along its course.

1.13 The Newnes Brook enters open channel for approximately 260m (120m of which is within the site) before it enters the Tetchill Brook culvert, via a weir arrangement/drop chamber. The weir is elevated above the soffit of the Tetchill Brook culvert, meaning that under flood conditions, flood water from the Newnes Brook can surcharge the culvert, effectively 'tide locking' the flow of water out of Ellesmere.

1.14 The local watercourse connectivity is illustrated within Figure 1.8.

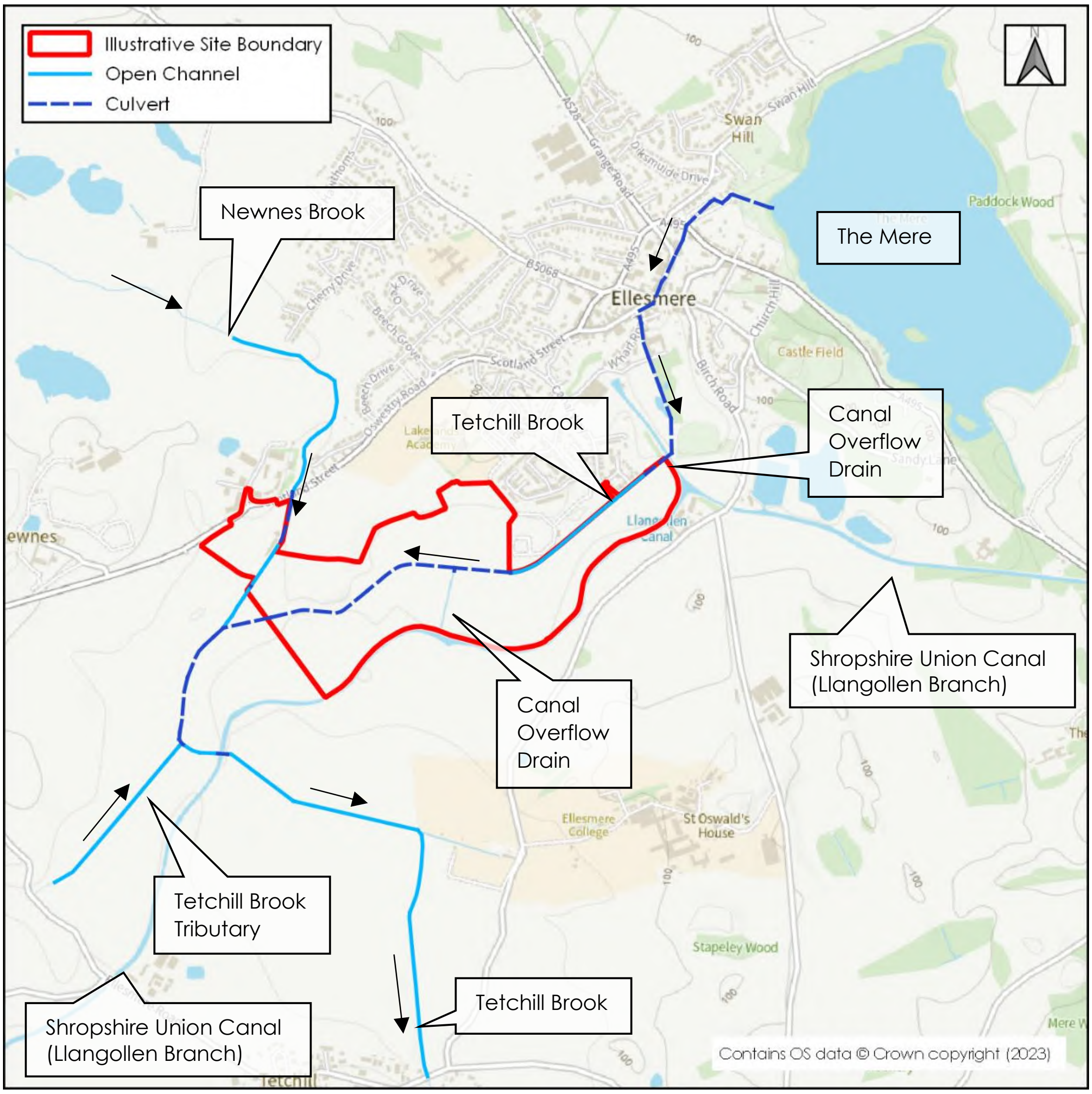

Figure 1.8: Watercourse Connectivity

1.15 The generalised topography of the site and surrounding area is illustrated within Figure 1.9 which is a combination of topographical surveys and EA 1m DTM LiDAR data.

1.16 The central and eastern proportion of the site is characterised by a central topographical low point where ground levels are in the region of 85.5 to 86.0mAOD. Ground level increase to the north to reach elevations in excess of 96.00mAOD, and to the south to meet the tow path of the canal (a continuous elevation of approximately 90.5mAOD). Land to the east and west is also raised above this central area in the site.

1.17 Therefore, there is no natural flow route in or out of the central and eastern areas of the site, other than via the Tetchill Brook culvert. Water enters the site via the culvert under the canal, and the elevated nature of the canal (at 90.5mAOD) acts as a barrier to overland flows; water leaves the site via the Tetchill Brook culvert, and the higher ground on the south-western boundary (in the region of 87.5mAOD) prevents any flood water from the Tetchill Brook from leaving the site via an overland route.

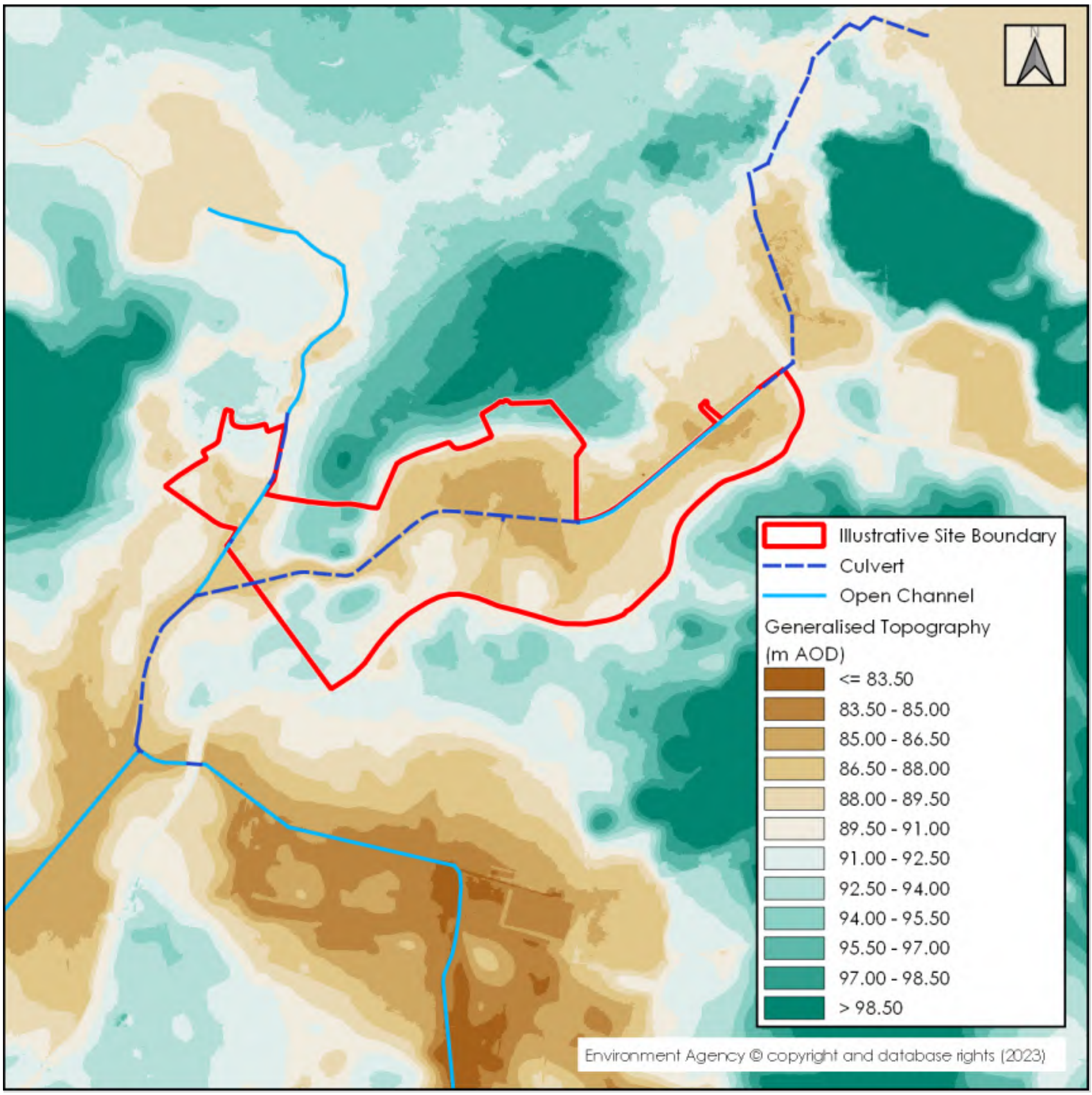

Figure 1.9: Generalised Topography

1.18 In the west of the site, the land generally falls from Scotland Street (A495) where ground levels are in the region of 90.0 to 92.0mAOD, towards the Newnes Brook and the south-western boundary where ground levels descend to approximately 87.5mAOD. Ground levels continue to fall away from the site further to the south west, providing an overland flow route away from the site above the culverted watercourse.

Proposed Development

1.19 The planning application includes the formation of a new Link Road with Footway and Cycleway Provision between the Ellesmere Business Park Roundabout on the A495 and Canal Way, including associated modification to the Ellesmere Business Park Roundabout, recontouring and earthworks throughout the site and formation of flood compensation areas. The proposed earthworks are illustrated in the engineering plans available in Appendix 4.

1.20 These enabling works precede, and will facilitate, a future residentially-led mixed-use development of the site, as illustrated with the indicative masterplan also included in Appendix 4.

2. FLOOD RISK PLANNING POLICY & GUIDANCE

National Planning Policy Framework

2.1 The NPPF[1] sets out the Government's national policies on different aspects of land use planning in England in relation to flood risk. Planning Practice Guidance is also available online[2].

2.2 The Planning Practice Guidance sets out the vulnerability to flooding of different land uses. It encourages development to be located in areas of lower flood risk where possible and stresses the importance of preventing increases in flood risk off site to the wider catchment area.

2.3 The Planning Practice Guidance also states that alternative sources of flooding, other than fluvial (river flooding), should be considered when preparing a Flood Risk Assessment.

2.4 The Planning Practice Guidance includes a series of tables that define Flood Zones (Table 1), the flood risk vulnerability classification of development land uses (Table 2) and 'compatibility' of development within the defined Flood Zones (Table 3). Table 2 and Table 3 are recreated within **Appendix 1** of this report for reference.

2.5 This Flood Risk Assessment is written in accordance with the NPPF and the Planning Practice Guidance.

Flood Map for Planning

2.6 With particular reference to planning and development, the Flood Map for Planning identifies Flood Zones in accordance with Table 1 of the Planning Practice Guidance. Further details on the Flood Zone classifications are outlined in **Table 2.1**.

Table 2.1: Flood Zone Classifications

Flood Zone	Description
Flood Zone 1 (Low Probability)	Land having less than a 1 in 1000 annual probability of river or sea flooding (<0.1% Annual Exceedance Probability (AEP)). All land outside of Flood Zone 2 and 3.
Flood Zone 2 (Medium Probability)	Land having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1% AEP); or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1% AEP).
Flood Zone 3a (High Probability)	Land having a 1 in 100 or greater annual probability of river flooding (>1% AEP); or land having a 1 in 200 or greater annual probability of flooding from the sea (>0.5% AEP). This is represented by "Flood Zone 3" on the Flood Map for Planning.

[1] Revised National Planning Policy Framework, Ministry of Housing, Communities & Local Government, amended July 2021
[2] Planning Practice Guidance: https://www.gov.uk/government/collections/planning-practice-guidance, updated August 2022

Flood Zone	Description
Flood Zone 3b (The Functional Floodplain)	Flood Zone 3b (The Functional Floodplain) is defined as land where water must flow or be stored in times of flood. This is not identified or separately distinguished from Zone 3a on the Flood Map for Planning. Typically, this is defined as land having a greater than a 1 in 30 annual probability of flooding (3.3% AEP) from rivers or sea, and land that is design to flood - such as a designated flood storage area. However, functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters.

2.7 The site is shown to be located across within Flood Zone 3 and 2 of the Tetchill and Newnes Brooks, as shown in Figure 2.1.

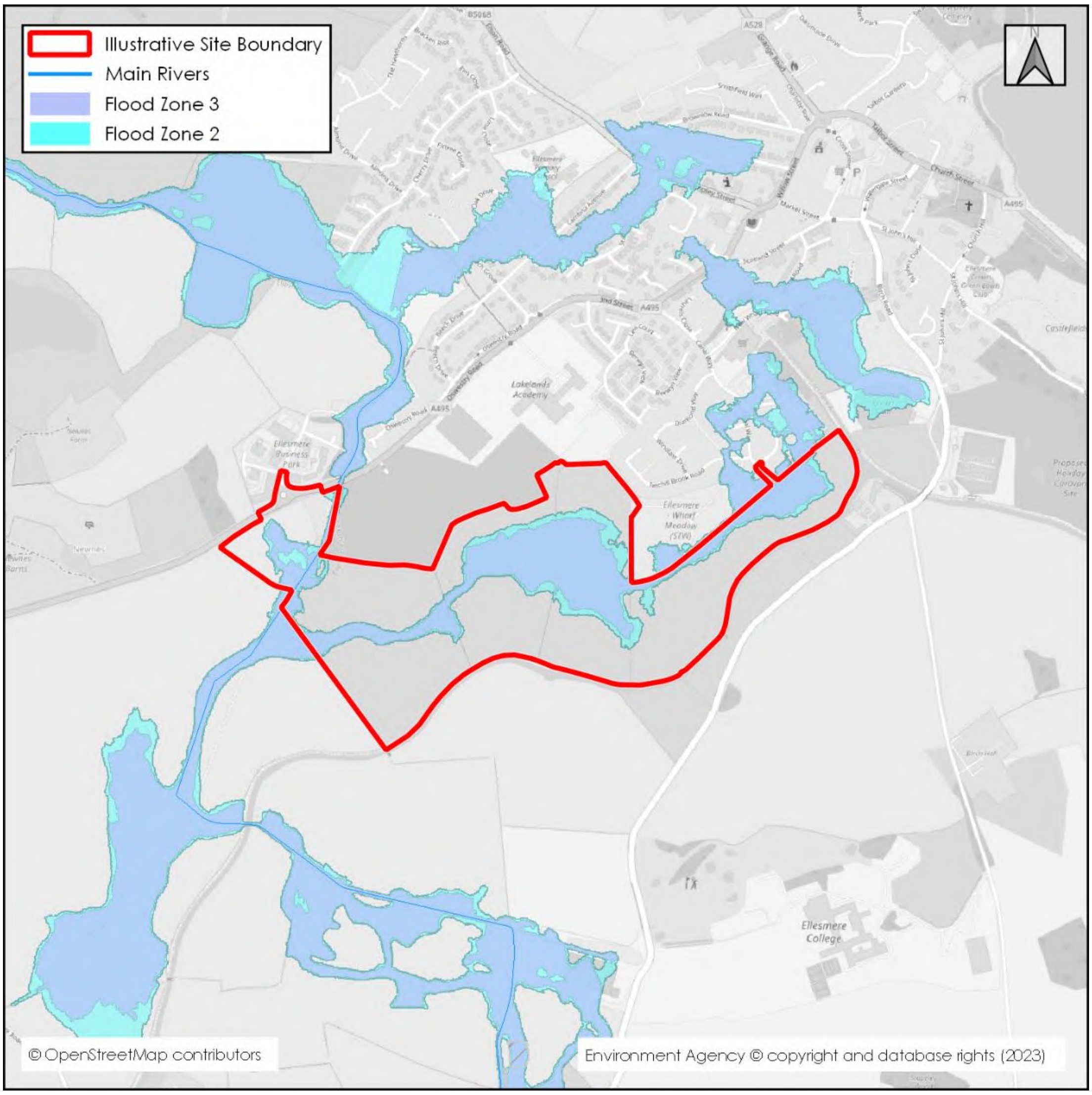

Figure 2.1: Flood Map for Planning

2.8 While the Flood Zones follow the general topography within the site, they become fragmented between the Tetchill Brook and Newnes Brook through Ellesmere. The mapped extents are believed to be based upon strategic level hydraulic modelling. This approach may have omitted important features such as the extensive culverted reaches on the Tetchill Brook. These omissions may have led to the over estimation of the floodplain extents in the site (as water is forced to pool to unrealistic depths), and the questionable flow routes through Ellesmere. Therefore, the Flood Map for Planning is not considered to be a reliable flood risk data source on which to base this FRA.

Site-Specific Flood Zones

2.9 In 2014 BWB Consulting prepared a hydraulic model of the Tetchill Brook and the Newnes Brook within the vicinity of the site. The model was peer reviewed by the EA and was identified to be fit for purpose under reference: SV/2013/107421/05.

2.10 Over the intervening years, a number of hydrology reviews have been completed and additional datasets added to the model, keeping it up to date with the latest software releases and methodologies, and also extending its coverage. The hydraulic model report, included as **Appendix 2**, provides a detailed description of the model.

2.11 The model provides the best available representation of floodplain at the site as it does include the extensive culverted reaches and other hydraulic structures. Floodplain outlines equivalent to Flood Zone 2, Flood Zone 3a, and Flood Zone 3b return period events are presented within **Figure 2.2**. These confirm that that Flood Zone 3b, 3a and 2 are present in the site, albeit to a lesser extent than what is represented in the national Flood Map for Planning.

Site Allocations and Management of Development Plan

2.12 Table 2 and Table 3 and the Planning Practise Guidance (recreated as **Appendix 1**) identify that water compatible development and essential infrastructure would only normally only be permitted in Flood Zone 3b.

2.13 However, as previously outlined, the site was allocated for development in December 2015 within the Shropshire Council Site Allocations and Management of Development (SAMDev) Plan[3], reference ELL003a (residential) and ELL003b (leisure and tourism). This allocation is subject to adopting a sequential approach to ensure that more vulnerable uses occupy areas of lowest flood risk, and that satisfactory drainage and flood risk measures are implemented.

2.14 The Council's draft Local plan 2016 – 2038 (December 2020), retains the site as an adopted development site (ref: ELL003a and ELL003b). The draft plan also states that the Sequential Test does not need to be applied to allocated sites.

2.15 Therefore, it is understood that the development of the site is considered appropriate by the Local Planning Authority.

[3] Shropshire Council Site Allocations and Management of Development (SAMDev) Plan. Shropshire Council, 2015)

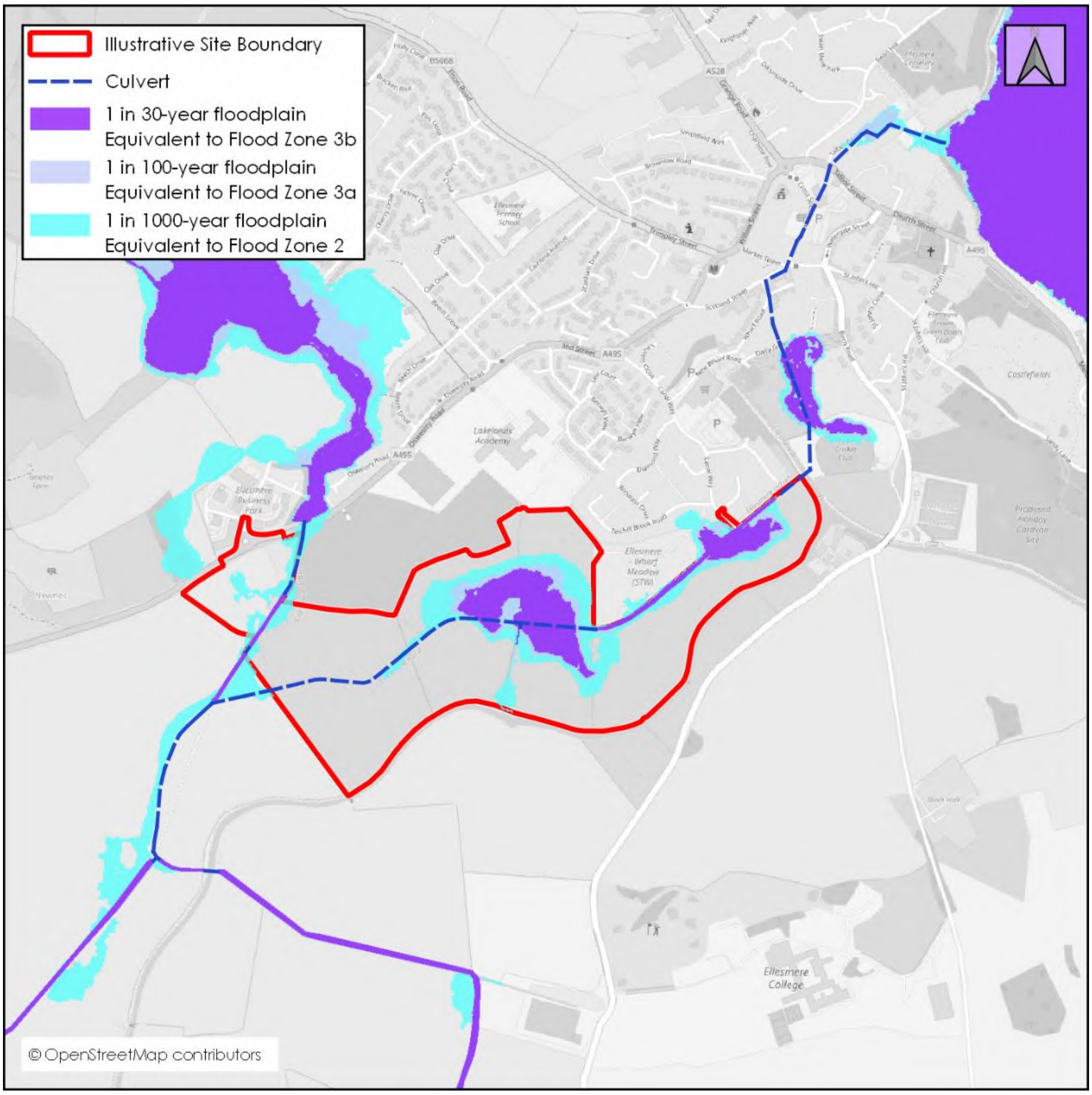

Figure 2.2: Site-Specific Flood Zones Derived from a Bespoke Hydraulic Model

The Exception Test

2.16 The two requirements of the Exception Test are provided within Table 2.2, along with details of how these are fulfilled by the proposed scheme.

2.17 Also, given a similar scheme was previously granted planning permission, it is understood that the principle of a development of this nature in this location has already been accepted.

Table 2.2: The Exception Test

Requirement	Evidence
Development that has to be in a flood risk area will provide wider sustainability benefits to the community that outweigh flood risk.	The proposed scheme includes for the de-culverting of a substantial length of the Tetchill Brook. This will help reinstate aquatic and riparian habitats, promote natural geomorphological processes, and improve access to, and amenity use of, the watercourse. The de-culverting and the associated floodplain rearrangement will also help reduce flood risk to the surrounding area through improved flood conveyance and storage, as well as a reduced risk of culvert collapse or blockage. This is discussed in Section 4 and shown in Appendix 5.
The development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall	This Flood Risk Assessment demonstrates that the development will be safe for its lifetime, that it will not increase flood risk elsewhere, and that it will also offer some reduction in flood risk to the surrounding area through the proposed de-culverting and floodplain re-arrangement works.

The Design Flood

2.18 The Planning Practice Guidance identifies that new developments should be designed to provide adequate flood risk management, mitigation, and resilience against the 'design flood' for their lifetime.

2.19 This is a flood event of a given annual flood probability, which is generally taken as fluvial (river) and surface water (pluvial) flooding likely to occur with a 1% annual probability (a 1 in 100 chance each year), or tidal flooding with a 0.5% annual probability (1 in 200 chance each year), plus an appropriate allowance for climate change.

Climate Change

Peak River Flow

2.20 Predicted future changes in peak river flows caused by climate change are provided by the Environment Agency (EA)[4], with a range of projections applied to regionalised 'River Basin Districts', which are further subdivided into Management Catchments.

2.21 The site falls within the Severn Middle Shropshire Management Catchment of the Severn River Basin District. Table 2.3 identifies the relevant peak river flow climate change allowances from this Management Catchment.

[4] Environment Agency, Flood risk assessments: climate change allowances: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances. Last Accessed October 2022.

Table 2.3: Peak River Flow Climate Change Allowances for the Severn Middle Shropshire Management Catchment within the Severn River Basin District

Allowance Category	Total potential change anticipated for the **'2020s' (2015 to 2039)**	Total potential change anticipated for the **'2050s' (2040 to 2069)**	Total potential change anticipated for the **'2080s' (2070 to 2125)**
Upper End	30%	42%	72%
Higher Central	20%	25%	44%
Central	15%	18%	33%

2.22 When determining the appropriate allowance for use in an FRA the Flood Zone classification, flood risk vulnerability, and the anticipated lifespan of the development should be considered. Table 2.4 provides a matrix summarising the EA's guidance on determining the appropriate allowance(s).

Table 2.4: Application of Appropriate Peak River Flow Climate Change Allowances

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
1	Use the central allowance where a location may fall within Flood Zone 2 or 3 in the future.				
2	Use the higher central allowance	Use the central allowance			
3a	Use the higher central allowance	Development should not be permitted	Use the central allowance		
3b	Use the higher central allowance	Development should not be permitted			Use the central allowance
If development is considered appropriate by the local authority when not in accordance with Flood Zone vulnerability categories, then it would be appropriate to use the higher central allowance.					

2.23 The site is located partially within Flood Zone 3b, elements of the proposed development are classified as 'more vulnerable', 'less vulnerable', and also as 'essential infrastructure', and it has an anticipated lifespan of over 100 years. Therefore, as the development is considered appropriate by the local authority, the Higher Central allowance for the '2080s' epoch will need to be considered.

2.24 Accordingly, to ensure the development is designed adequately for its lifetime an allowance of 44% will be applied to the design flood event when determining the parameters of the flood management scheme.

2.25 To ensure the safety of people using the development when designing safe access, escape routes and places of refuge, the EA guidance identifies that it is appropriate to use the central allowance, except for essential infrastructure, where the higher central allowance should be used. Therefore, for this scheme an allowance of 44% will be applied to the design flood event when determining minimum levels for the link road.

2.26 When determining the potential off-site impacts of a proposed development, its vulnerability is not critical, instead the land use in the wider floodplain needs to be considered. In their online guidance, the EA advise that generally it is appropriate to use the central allowance. Therefore, flood events up to and including the 1 in 100-year+33% return period flood will be used to assess the impact of the proposed scheme and any necessary floodplain compensatory measures.

Peak Rainfall

2.27 Predicted future changes in peak rainfall intensity caused by climate change are provided by the EA[5], with a range of projections applied to River Basin District Management Catchments. Table 2.5 identifies the relevant peak rainfall climate change allowances for the Severn Middle Shropshire Management Catchment.

Table 2.5: Peak Rainfall Climate Change Allowances for the Severn Middle Shropshire Management Catchment

Allowance Category	Total potential change anticipated for the '2050s' epoch (2022 to 2060)		Total potential change anticipated for the '2070s' epoch (2061 to 2125)	
	1 in 30-Year	1 in 100-Year	1 in 30-Year	1 in 100-Year
Upper End	35%	40%	40%	45%
Central	20%	25%	25%	30%

2.28 The future increase in rainfall will need to be considered when designing a development to ensure its drainage system is sufficient for its lifetime and that it does not increase flood risk elsewhere. Table 2.6 provides a matrix summarising the EA's guidance on determining the appropriate allowance(s).

5 Environment Agency, Flood risk assessments: climate change allowances: Environment Agency, Flood risk assessments: climate change allowances: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances. Last Accessed October 2022.

Table 2.6: Application of Appropriate Peak Rainfall Climate Change Allowances

Area Assessed	Anticipated Development Life Span		
	up to 2060	between 2061 and 2100	up to or beyond 2100*
Development Sites^ Assess the 1 in 30-year and 1 in 100-year storm events with the respective climate change allowance(s) applied. Development to be designed so that with the climate change allowance applied to the 1 in 100-year storm: • there is no increase in flood risk elsewhere • the development will be safe from surface water flooding	Use the Central Allowance for the 2050s	Use the Central Allowance for the 2070s+	Use the Upper End Allowance for the 2070s+

**Includes all residential developments*
^the Lead Local Flood Authority may have local standards that also need to be considered.
+unless the 2050s allowance is greater

2.29 The development site has an anticipated lifespan of over 100 years. Therefore, the Upper End allowance for the '2070s' epoch (+45%) will need to be considered in the design of the associated drainage infrastructure.

Strategic Flood Risk Assessment

2.30 A Strategic Flood Risk Assessment (SFRA) is a study carried out by one or more local planning authorities to assess the risk to an area from flooding from all sources, now and in the future.

2.31 The Shropshire Council Level 1 SFRA[6] has been reviewed in the production of this FRA. The SFRA provides information specific to the site location in the form of fluvial, surface water and groundwater flood risk mapping, as well as records of historic flooding. However, the SFRA does not contain any historical or site-specific information relevant to the site.

2.32 The SFRA identifies that new development should seek to consider the following:

- Will the natural watercourse system, which provides drainage of land, be adversely affected?
- Will a minimum 8m width access strip be provided adjacent to the top of both banks of any Main River (5m for Ordinary Watercourses), for maintenance purposes and is appropriately landscaped for open space and biodiversity benefits?
- Will the development ensure no loss of open water features through draining, culverting or enclosure by other means and will any culverts be opened up?
- Sustainable drainage systems are given priority to manage surface water flood risk.

[6] Shropshire Council Strategic Flood Risk Assessment Level 1, JBA (October 2018)

- Will there be a betterment in the surface water runoff regime; with any residual risk of flooding, from drainage features either on or off site not placing people and property at unacceptable risk?
- Is the application compliant with the conditions set out by the LLFA?
- Flood risk reduction opportunities should be sought/improved in the fluvial flood risk regime.

2.33 These have been considered in the preparation of this FRA.

Preliminary Flood Risk Assessment

2.34 A Preliminary Flood Risk Assessment (PFRA) is an assessment of floods that have taken place in the past and floods that could take place in the future. It generally considers flooding from surface water runoff, groundwater and ordinary watercourses, and is prepared by the Lead Local Flood Authorities (LLFA).

2.35 The Shropshire Council PFRA[7] does not record any flood risk areas of national significance within the county nor does it reference any historical instances of flooding at the site.

Water Cycle Strategy

2.36 A Water Cycle Strategy (WCS) is prepared by the Local Planning Authority to establish where constraints to development exist and to identify measures to eliminate or mitigate such constraints through the planning process. A WCS incorporates a strategic assessment of water resources and supply, sewerage and waste water treatment systems.

2.37 The Shropshire Outline Water Cycle Strategy[8] identifies that there are no known waste water capacity issues in Ellesmere, but that there was limited information on waste water treatment and dry weather flows for a complete analysis. It states that fluvial flood risk will be a constraint to development in south of Ellesmere, along with some surface water flood risk.

Local Flood Risk Management Strategy

2.38 A Local Flood Risk Management Strategy (LFRMS) is prepared by a Lead Local Flood Authority to help understand and manage flood risk at a local level.

2.39 The LFRMS aims to ensure that the knowledge of local flood risk issues is communicated effectively so that they can be better managed. The LFRMS also aims to promote sustainable development and environmental protection.

2.40 The Shropshire LFRMS[9] makes reference to the strategic flood risk in Ellesmere (based on the Flood Maps for Planning), but it does not discuss the site or any historical incidents.

[7] Preliminary Flood Risk Assessment, Shropshire Council (2011)
[8] Shropshire Outline Water Cycle Strategy, Halcrow Group (2010)
[9] Local Flood Risk Management Strategy (Shropshire Council, 2015)

2.41 The LFRMS identifies that new development should seek to include Sustainable Drainage Systems (SuDS) where possible to help manage local flood risk issues.

River Basin Flood Risk Management Plan

2.42 Flood risk management plans (FRMPs) explain the risk of flooding from rivers, the sea, surface water, groundwater and reservoirs. FRMPs set out how risk management authorities will work with communities to manage flood and coastal risk. Risk management authorities include the Environment Agency, Natural Resources Wales, local councils, internal drainage boards, Highways England and Lead Local Flood Authorities (LLFAs).

2.43 The first FRMPs were published in March 2016, and were subsequential updated in 2022. They describe actions to manage flood risk across England between 2021 to 2027.

2.44 The site is located within the Severn River Basin District, Upper River Severn Catchment. Thethe Severn FRMP[10] has been reviewed and the relevant objectives have been considered in **Section 4** of this report. This includes implementing measures that reduce flood risk, and seeking opportunities to support the management of water resources and enhances the environment.

Surface Water Management Plan

2.45 Surface Water Management Plan SWMPs is a detailed investigation into local sources of flood risk such as small watercourses, piped drainage systems and overland flow routes. They are non-statutory plans prepared by the Local Authority which preceded the introduction of the Flood and Water Management Act 2010. They can provide an important evidence base of local flood risk issues which can include surface water drains, groundwater and small watercourses.

2.46 An SWMP for Ellesmere could not be found on Shropshire's website.

Local Plan

2.47 Shropshire's 2011 Local Development Framework (the adopted core strategy for 2006-2026)[11] addresses water and flood risk management under policy CS18: Sustainable Water Management, which stipulates the following:

- Planning applications and allocations in the Site Allocations and Management of Development (SAMDev) DPD, are in accordance with the tests contained in PPS25, and have regard to the SFRAs for Shropshire;
- New development is designed to be safe, taking into account the lifetime of the development, and the need to adapt to climate change. Proposals should have regard to the design guidance provided in the SFRAs for Shropshire;
- All development within local surface water drainage areas, as identified by the Water Cycle Study, and any major development proposals, demonstrate that surface water will be managed in a sustainable and coordinated way. Proposals will

[10] Severn Flood Risk Management Plan. (Natural Resources Wales, Environment Agency, 2021.
[11] Shropshire Local Development Framework: Adopted Core Strategy. Shropshire Council, 2011.

be supported by either a Surface Water Management Statement or Plan, depending on the scale of the development;

- All developments, including changes to existing buildings, include appropriate sustainable drainage systems (SUDS) to manage surface water. All developments should aim to achieve a reduction in the existing runoff rate, but must not result in an increase in runoff;
- New development improves drainage by opening up existing culverts where appropriate;
- Proposals within areas of infrastructure capacity constraint, as identified by the Water Cycle Study and the Implementation Plan, and any major development, demonstrates that there is adequate water infrastructure in place to serve the development;
- New development enhances and protects water quality, including Shropshire's groundwater resources;
- New development, including changes to existing buildings, incorporate water efficiency measures, in accordance with the sustainability checklist in Policy CS6, to meet the water efficiency objectives within the Shropshire Water Cycle Study to protect water resources and reduce pressure on wastewater treatment infrastructure.

2.48 The Council's draft Local Plan for 2016 – 2038[12], retains the site as an adopted development site (ref: ELL003a and ELL003b). Flood risk is addressed by policies DP21 (Flood Risk) & DP22 (Sustainable Drainage) which have both been considered in the preparation of this FRA.

Other Relevant Policy and Guidance

2.49 This FRA has considered the following documents when assessing sources of flood risk and when recommending mitigation and resilience measures.

Improving the Flood Performance of New Buildings; Flood Resilient Construction

2.50 The Flood Resilient Construction[13] document is the outcome of a joint research project between Communities and Local Government and the Environment Agency. A Research and Development Technical Report[14] is also available.

2.51 The document provides guidance on flood resilient design and construction and possible techniques and building materials. These documents are referred to in this Flood Risk Assessment and have been considered when recommending mitigation and resilience measures.

[12] Regulation 19: Pre-Submission Draft of the Shropshire Local Plan 2016 to 2038. Shropshire Council December 2020
[13] Improving the Flood Performance of New Buildings; Flood Resilient Construction, CLG, May 2007
[14] Flood Resistance and Resilience Solutions; an R&D Scoping Study, Defra/Environment Agency, 2007

Development and Flood Risk – Guidance for the construction industry

2.52 The Development and Flood Risk guidance document[15] was prepared to advise on best practise in the assessment and management of flood risk as part of the development process, the document promotes sustainable development in terms of flood risk.

2.53 While many of the polices referenced in the document have been superseded, the principles of assessing and managing flood risk sustainably remain the same, and it remains one of the only guidance documents for the implementation of floodplain compensatory storage.

[15] C624 Development and Flood Risk – Guidance for the construction industry, CIRIA, 2004

3. POTENTIAL SOURCES OF FLOOD RISK

3.1 Flooding can occur from a variety of sources, or combination of sources, which may be natural or artificial. These are discussed in the forthcoming section. The mitigation measures proposed to address flood risk issues and ensure the development is appropriate for its location are discussed within Section 4.

Historical Flooding Incidents

3.2 Consultation with the EA, LLFA, Canal and River Trust (CRT), tenant farmer, and landowner, along with reviews of local news outlets, and the SFRA and PFRA have revealed no reported or anecdotal history of flooding on the site.

Coastal

3.3 Inundation of low-lying coastal areas by the sea may be caused by seasonal high tides, storm surges and storm driven wave action. Coastal flooding is most commonly a result of a combination of two or more of these mechanisms, which can result in the overtopping or breaching of sea defences. River systems may also be subject to tidal influences.

3.4 Due to its inland location, coastal processes do not pose a risk to the site.

Fluvial Flood Risk

3.5 Flooding from watercourses occurs when flows exceed the capacity of the channel, or where a restrictive structure is encountered, which leads to water overtopping the banks into the floodplain. This process can be exacerbated when debris is mobilised by high flows and accumulates at structures.

3.6 As previously discussed, a hydraulic model of the Tetchill Brook and the Newnes Brook within the vicinity of the site was first developed in 2014 to help secure outline planning. The model was peer reviewed by the EA and was identified to be fit for purpose under reference: SV/2013/107421/05. Over the intervening years, a number of hydrology reviews have been completed and additional datasets added to the model, keeping it up to date with the latest software releases, climate change allowances, methodologies, and also extending its coverage. The hydraulic model report, included as Appendix 2, provides a detailed description of the model, along with floodplain maps and sensitivity tests. The modelled floodplain at the site is illustrated within Figure 3.1 with peak flood levels provided in Table 3.1 for ease of reference.

3.7 Given the lack of any observed flood history on the site, the modelled floodplain extents are considered over-estimates and precautionary.

Newnes Brook

3.8 On the Newnes Brook in the west of the site, the culvert beneath the A495 (1.5m diameter pipe reducing to a 1.05m diameter pipe at its outfall) is shown to be a significant restriction on flood flows, which attenuates flood water upstream of the site.

3.9 At the 1 in 100-year+33%, 1 in 100-year+44%, and 1 1in 1000-year return period flood events, flood levels are sufficient to generate a flow route that overtops the A495 and re-enters the channel downstream of the A495 culvert.

3.10 Between the A495 and Tetchill Brook culvert, the Newnes Brook floodplain remains relatively close to the channel. Out of bank flooding is only predicted in the 1 in 100-year+33%, 1 in 100-year+44%, and 1 1in 1000-year return period flood events, and this is due to the additional flood water overtopping the A495.

3.11 At the confluence with the Tetchill Brook, flood water enters the culvert via a drop chamber. When the capacity of this structure is exceeded, flood water ponds within the upstream channel, this creates a head difference that generates a backwater effect on the upstream Tetchill Brook. At the 1 in 1000-year event, flood levels are sufficient to overtop bank levels on the Newnes Brook, and flow downstream over the top of the culvert, where it re-enters open channel immediately upstream of the canal.

Tetchill Brook

3.12 The hydraulic model identifies that Newnes Brook has an important influence on the flow dynamics on the Tetchill Brook culvert. Due to the Newnes' elevated position at the confluence with the Tetchill Brook culvert, a large ingress of water can be directed up the Tetchill Brook culvert, as well as down the culvert due to the hydraulic head difference. This has the effect of reducing the capacity of the Tetchill Brook culvert to convey flood flows away from Ellesmere, and in the more extreme events (the 1 in 100-year+44% and the 1000-year events) flow in the culvert is reversed. This backwater effect can extend from the confluence with the Newnes Brook to New Dairy Grove/Wharf Road upstream of the site.

3.13 The flood water entering the site from the upstream Tetchill Brook is limited by the capacity of the upstream culverted reaches though the town and beneath the canal. Flood water in excess of the culvert capacity on this reach floods a playing field/cricket pitch located on the opposite side of the canal to the site. The raised nature of the canal prevents any overland flows from entering the site from this location.

3.14 The relatively low-lying topography in the eastern and central areas of the site is positioned between the high ground of the upstream canal embankment and the downstream topography, which rises to meet the Newnes Brook. The Tetchill Brook is culverted beneath some of the area, but there is an open reach present immediately downstream of the canal. Flows on the Tetchill Brook leaving the site are restricted by the capacity of the downstream culvert, and the influence of the backwater effect from the Newnes Brook. No overland flows out of the floodplain can occur due to the elevated topography surrounding the site. Therefore, the combined flood water from the surcharging Newnes Brook and Tetchill Brook accumulate on the floodplain in the eastern and central areas of the site until downstream flood levels recede and it can drain back to the culvert/channel.

Residual Risks

3.15 A series of tests were undertaken during the 1 in 100-year flood event within the hydraulic model to understand the networks sensitivity to changes in hydraulic parameters. Full details are provided within Appendix 2.

3.16 Changes in flow and roughness were identified to influence flood levels in the site by between -0.17 to 0.13m, but the largest influence was found to be potential blockages of the culverts in and around the site.

3.17 Blockages of the culverts upstream of the site, especially under the A495 on the Newnes Brook, were shown to reduce flood levels in the site by up to 0.54m. Whereas, blockages of the culverts within and downstream of the site were shown to increase flood levels by up to 0.89m. The blockage with the most detrimental impact on the site was a blockage of the Tetchill Brook culvert immediately downstream of the confluence with the Newnes Brook (ref: Blockage 8 - BL8).

3.18 Given the potential impact of a downstream blockage it is recommended that the implications of this are considered at the 1 in 100-year +44% event when determining minimum development levels. This is discussed within Section 4.

Summary

3.19 The Newnes and Tetchill Brook both pose a potentially high risk of flooding to parts of the site that will need to be addressed by the proposed scheme. There is also a residual flood risk posed by a potential blockage of the downstream culverts that the proposed scheme should also consider. The measures proposed to address these risks are discussed within Section 4.

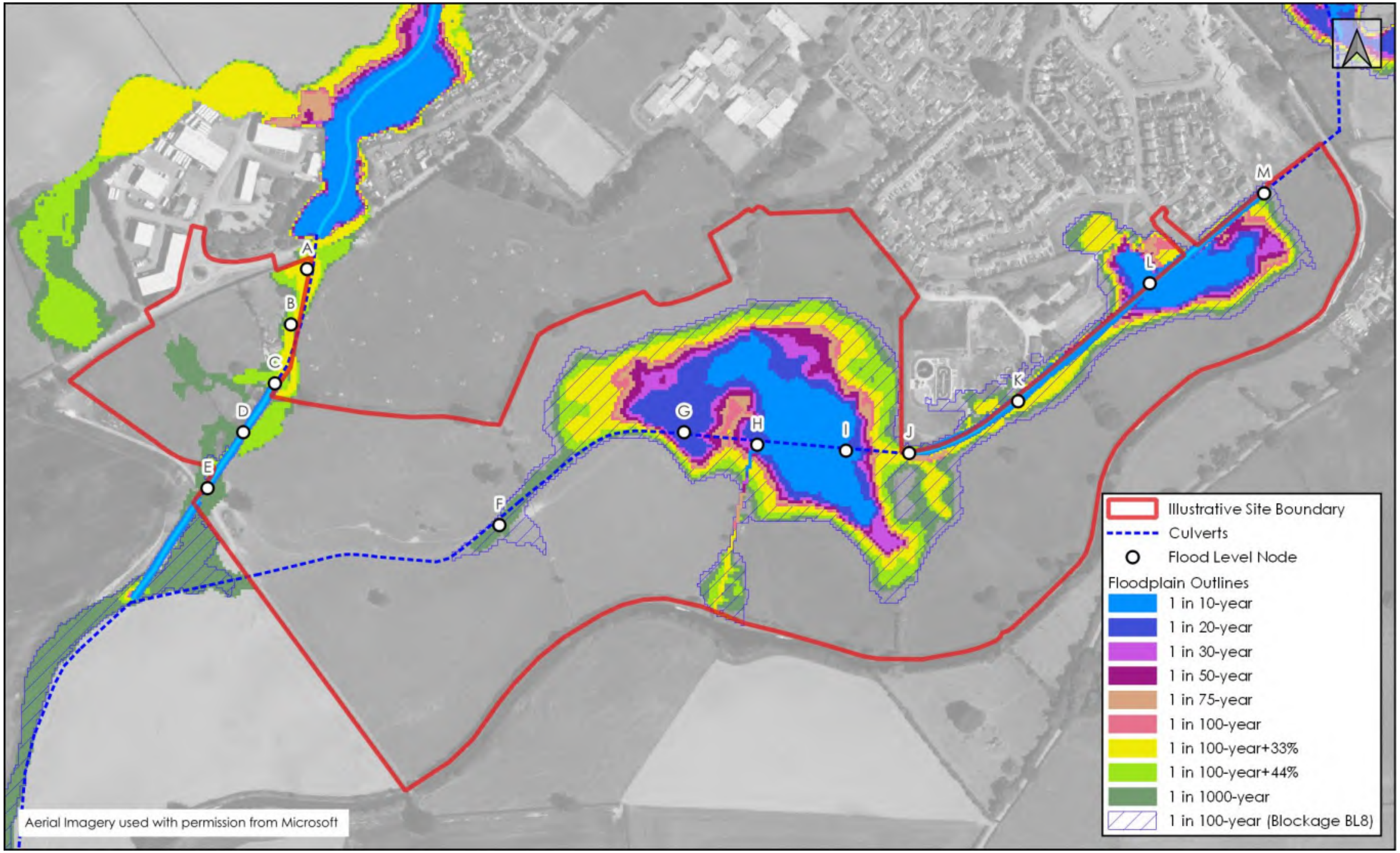

Figure 3.1: Baseline Floodplain Outlines

Table 3.1: Baseline Peak Flood Levels

Flood Level Node	Peak Flood Level (m AOD)										
	1 in 5yr	1 in 10yr	1 in 20yr	1 in 30yr	1 in 50yr	1 in 75yr	1 in 100yr	1 in 100yr +33%	1 in 100yr +44%	1 in 1000yr	1 in 100yr BL8
A	-	-	-	-	-	-	-	90.05	90.20	90.38	-
B	-	-	-	-	-	-	-	89.94	90.09	90.26	-
C	87.25	87.26	87.28	87.29	87.31	87.32	87.33	87.38	87.59	87.90	87.55
D	87.01	87.02	87.05	87.07	87.09	87.10	87.11	87.18	87.46	87.79	87.49
E	86.87	86.88	86.91	86.93	86.95	86.97	86.98	87.06	87.39	87.72	87.47
F	-	-	-	-	-	-	-	-	-	87.10	87.28
G	-	-	86.18	86.26	86.37	86.44	86.49	86.70	86.92	87.10	87.28
H	86.07	86.08	86.18	86.26	86.37	86.44	86.49	86.70	86.92	87.10	87.28
I	-	86.02	86.18	86.26	86.37	86.44	86.49	86.70	86.92	87.10	87.28
J	86.25	86.36	86.48	86.54	86.62	86.69	86.74	86.89	86.93	87.10	87.28
K	86.25	86.36	86.48	86.54	86.62	86.69	86.74	86.89	86.93	87.10	87.28
L	86.25	86.36	86.48	86.55	86.63	86.69	86.74	86.89	86.93	87.10	87.28
M	86.25	86.36	86.48	86.55	86.63	86.69	86.74	86.89	86.93	87.10	87.28

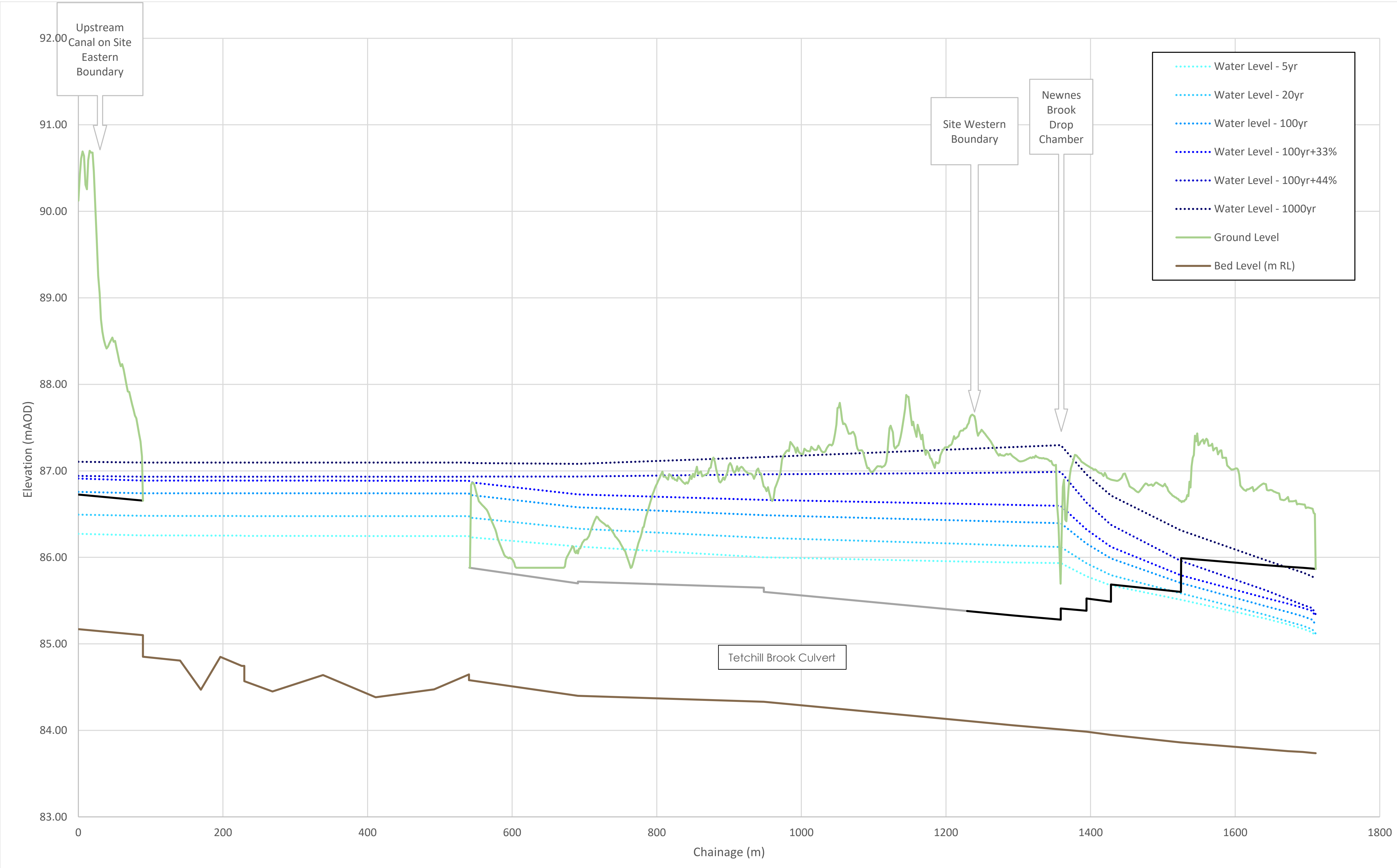

Figure 3.2: Long Section Through the Tetchill Brook within the Vicinity of the Site

Pluvial Flood Risk

3.20 Pluvial flooding can occur during prolonged or intense storm events when the infiltration potential of soils, or the capacity of drainage infrastructure is overwhelmed leading to the accumulation of surface water and the generation of overland flow routes.

3.21 Risk of Flooding from Surface Water (RoFSW) mapping has been collated and published by the EA. This shows the potential flooding which could occur when rainwater does not drain away through the normal drainage systems or soak into the ground but lies on or flows over the ground instead. An extract from the mapping is included as Figure 3.3.

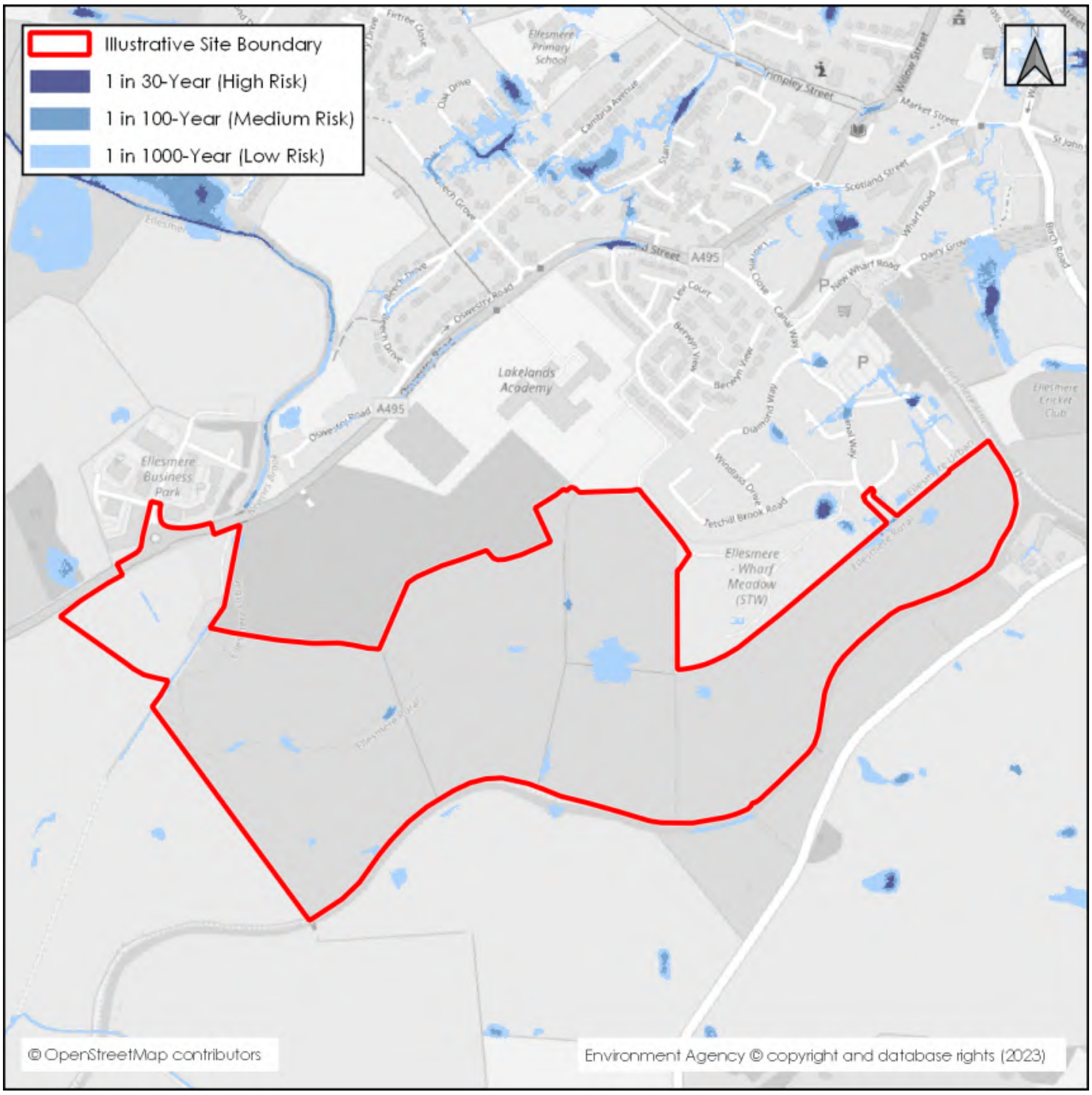

Figure 3.3: Risk of Flooding from Surface Water Map

3.22 The site in its existing condition is identified to be at a low to very low risk of surface water flooding.

3.23 However, the increased runoff from the new impermeable surfaces introduced by the proposed development will need to be addressed by the proposed scheme. This is discussed within Section 4.

Flood Risk from Sewers

3.24 Sewer flooding can occur when the capacity of the infrastructure is exceeded by excessive flows, or as a result of a reduction in capacity due to collapse or blockage, or if the downstream system becomes surcharged. This can lead to the sewers flooding onto the surrounding ground via manholes and gullies, which can generate overland flows.

3.25 Severn Trent sewer records show that there are adopted surface and foul water networks to the north of the site (as shown in Appendix 3).

3.26 Although the land to the north of the site is generally higher than the site, it is likely that in the event that the sewers flood, the resultant overland flows would be intercepted before they reach the site, either by the highway drainage systems or by the Tetchill or Newnes Brook fluvial systems.

3.27 The sewer records also report that a 100mm diameter rising main crosses the site. This is subject to a 5.0m protection zone, which could be diverted if necessary.

3.28 While the flood risk from the existing sewer networks around the site is low, the development will include a new sewer network, and the proposed scheme should be designed to consider the potential risk of exceedance from this. This is discussed within Section 4.

Groundwater Flood Risk

3.29 Groundwater flooding occurs when the water table rises above ground elevations, or it rises to depths containing basement level development. It is most likely to happen in low lying areas underlain by permeable geology. This is most common on regional scale chalk aquifers, but there may also be a risk on sandstone and limestone aquifers or on thick deposits of sands and gravels underlain by less permeable strata such as that in a river valley.

3.30 The site is identified to be within an area of freely draining soil material as shown on British Geological Survey (BGS) geology and soil maps. The underlying bedrock is understood to be Wilmslow Sandstone and forms part of a Principal (Major) Aquifer system capable of storing large quantities of water within bedrock. Superficial deposits underlying the majority of the site are indicated to consist of Glacial Till. Glaciofluvial Deposits and Alluvium are however indicated to outcrop in the western end of the site.

3.31 Phase I and Phase 2 Geo-Environmental Assessments undertaken by BWB identified that ground conditions comprise firm and stiff, locally soft sandy gravelly clay with bands of sand and gravel of the Glacial Till proven to a maximum depth of 10.45mBGL. Localised areas of soft organic Alluvial clays and peat deposits were recorded to depths in excess of 3.8mBGL in the central area. Groundwater was recorded at depths between

0.66mBGL and 4.77mBGL in isolated areas. However, for the majority of the site no groundwater strikes were recorded. Therefore, it was concluded that the groundwater that was encountered is associated with perched water trapped within granular pockets.

3.32 No historical records of the site area being affected by groundwater flooding have been discovered or obtained.

3.33 Although there is no documented history of groundwater emergence on the site, there is a risk that the water table may be linked with the Tetchill Brook and Newnes Brook. Therefore, the potential flood risk posed by this source will be addressed in the same manner as the fluvial flood risk. This is discussed within Section 4.

3.34 The risk of encountering groundwater may increase during deep excavations undertaken as part of the construction stage. This may require additional temporary mitigation measures, which are also discussed within Section 4.

Flood Risk from Canals

3.35 The Canal and River Trust (CRT) generally maintains canal levels using reservoirs, feeders and boreholes and manages water levels by transferring it within the canal system.

3.36 Water in a canal is typically maintained at predetermined levels by control weirs. When rainfall or other water enters the canal, the water level rises and flows out over the weir. If the level continues rising it will reach the level of the storm weirs. The control weirs and storm weirs are normally designed to take the water that legally enters the canal under normal conditions. However, it is possible for unexpected water to enter the canal or for the weirs to become obstructed. In such instances the increased water levels could result in water overtopping the towpath and flowing onto the surrounding land.

3.37 Flooding can also occur where a canal is impounded above surrounding ground levels and the retaining structure fails.

3.38 The site is located directly adjacent to the Shropshire Union Canal (Llangollen Branch). A water level of 90.24mAOD was taken when the site was surveyed in November 2010. Ground levels along the canal bank adjacent to the site were surveyed between 90.5mAOD and 90.8mAOD, indicating that there was an approximate freeboard of 0.3m in place.

3.39 The tow path levels are higher than ground levels on site, implying that should water levels in the canal exceed the freeboard, floodwater could be directed onto site. The Canal and River Trust were contacted for information on this section of canal, who confirmed that there have been no record of historical breach or overtopping events on this stretch.

3.40 The CCTV and site topographical surveys identified two sluice gates within the vicinity of the site (see Figure 3.4). The first is located to the east of the site and discharges to the Tetchill Brook upstream of the site. The second is located on the southern boundary and discharges to a ditch which passes through the site on its way to the Tetchill Brook.

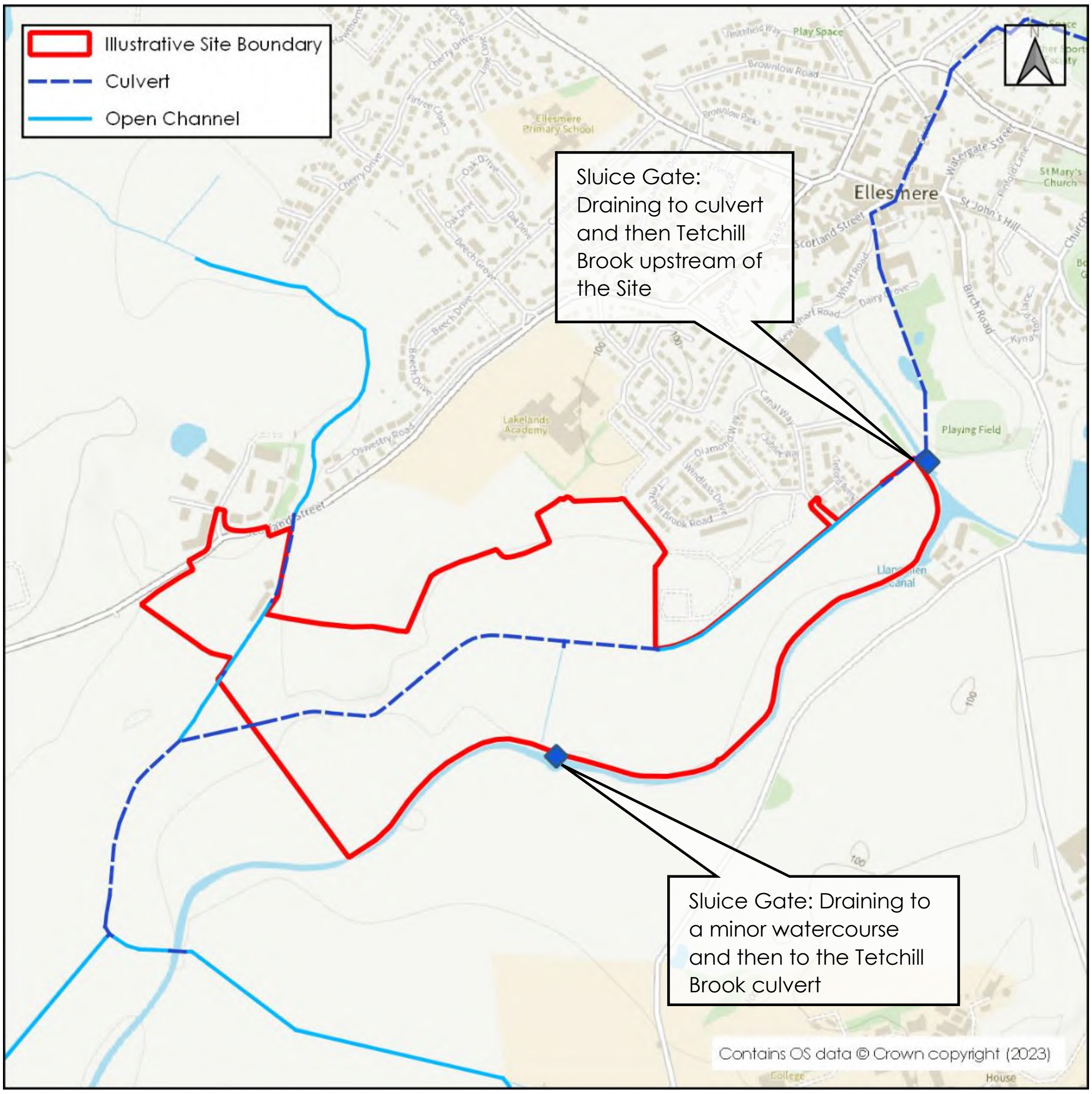

Figure 3.4: Canal Sluice Locations (CRT Assets)

3.41 The hydraulic model of the local watercourses, discussed previously, was informed by a hydrological estimation of flood flow on the Newnes and Tetchill Brook. These catchments include a 4.3km length of canal. Therefore, the contributing flow from the canal to the Tetchill Brook via these outfalls into the site are at least partially reflected in the modelled floodplain.

3.42 The CRT report that the water level in the canal is controlled by a number of weirs and sluice gates located along its pound length. Therefore, the risk of the canal exceeding its bank levels is considered to be low. However, given the close proximity of the canal, the residual flood risk it poses should be considered within the development proposals (discussed with Section 4.0).

Flood Risk from Reservoirs & Large Waterbodies

3.43 Flooding can occur from large waterbodies or reservoirs if they are impounded above the surrounding ground levels or are used to retain water in times of flood. Although unlikely, reservoirs and large waterbodies could overtop or breach leading to rapid inundation of the downstream floodplain.

3.44 To help identify this risk, reservoir failure flood risk mapping has been prepared by the EA, this shows the largest area that might be flooded if a reservoir were to fail and release the water it holds. The map displays a worst-case scenario and is only intended as a guide.

3.45 There are two flooding scenarios shown on the reservoir flood maps: a 'dry-day' and a 'wet-day'. The dry-day scenario predicts the flooding that would occur if the dam or reservoir failed when rivers are at normal levels. The wet-day scenario predicts how much worse the flooding might be if a river is already experiencing an extreme flood. The site is not shown to be risk of flooding in either scenario.

Summary

Table 3.2: Pre-Mitigation Sources of Flood Risk

Flood Source	Existing Risk	Comment
Coastal/Tidal	None	-
Fluvial	High	While there is no historical evidence of flooding on the site, the Newnes and Tetchill Brook both potentially pose a flood risk to the site under the right conditions that the proposed scheme will need to consider.
Pluvial / Surface Water	Low	While surface water runoff into the site from third party land poses a low risk, the increased runoff from the new impermeable surfaces introduced by the development will need to be addressed by the proposed scheme.
Sewers	Low	The existing sewer networks around the site pose a low risk to the site due to the intervening topography and watercourses. However, the development will include a new sewer network, and the proposed scheme should be designed to consider the potential risk of exceedance of this infrastructure.
Groundwater	Moderate	Intrusive investigations only encountered localised perched groundwater, and no record or evidence of groundwater flooding on the site or in the local area was found. However, there is a chance that groundwater will rise in continuity with the fluvial floodplain. Also, there is a risk that groundwater could be encountered during deep excavations that may be required during the construction phase.

Flood Source	Existing Risk	Comment
Canals	Moderate	The canal has two sluice gates which discharge to the Tetchill Brook within close proximity to the site. 4.3km of canal is included in the Tetchill Brook catchment used to derive the flood flows into the fluvial model to account for this contribution. While the CRT does not have any records of such an occurrence ever happening, there is a residual risk that the canal could overtop into the site adding more water to the floodplain. This residual risk should be considered by the proposed scheme.
Reservoirs and waterbodies	None	-

4. FLOOD RISK MITIGATION

4.1 Section 3 has identified the sources of flooding which could potentially pose a risk to the site. This section of the FRA sets out the mitigation measures which are to be incorporated within the proposed development to address and reduce the risk of flooding to within acceptable levels.

4.2 In 2014 a conceptual scheme was outlined and agreed with the EA and Local Authority, which included the de-culverting a stretch of Tetchill Brook, and consolidation of the floodplain within formalised storage areas. This would have allowed the development parcels to be elevated above flood levels without affecting flood risk in the wider area. The general principles of this previous permission are reflected in the latest proposals.

Flood Management Philosophy

4.3 In line with local policy and the preceding outline planning permission, it is proposed to daylight approximately 620m of the Tetchill Brook culvert within the site. This will help the watercourse move towards a more natural hydrological and geomorphological regime, while also allowing aquatic and riparian habitats to be reinstated and improving its amenity value.

4.4 The de-culverting provides the opportunity for the existing floodplain on the site to be rearranged into formalised areas. This will allow the land parcels to be raised out of the floodplain to create safe and sustainable zones for development.

4.5 However, it is not possible for the development to remove all of the culverted reaches within the vicinity of the site:

- A substantial length of culvert (475m) is located downstream of the site, this is outside of the site's control and so cannot be removed.
- It will be necessary to retain a short reach of culvert in the east of the site, where the new strategic road connection needs to cross the watercourse. There is a gas main in this location, and it is understood that this makes replacing the existing culvert with a new structure impractical.
- A length of culvert on the Tetchill Brook downstream of the canal in the very east of the site will also be retained. This is positioned on the site boundary and therefore any de-culverting works would impact third party land, which makes it unfeasible.
- A length of culvert on the Newnes Brook downstream of the A495 is also to be retained, this also falls on the site boundary and would require works to third party land to remove it. This structure is also an important throttle to flood water entering the site. If the culvert were to be removed, additional flood water would enter the site and increase flood risk to the site and Ellesmere.

4.6 Additionally, three new hydraulic structures will be required within the site to facilitate development:

- There is a need to reconnect the new open channel back to the retained downstream culvert on the Tetchill Brook. A new length of culvert is proposed to achieve this. This will be of a similar size to the downstream culvert to avoid creating any significant changes in dimensions within the culverted system that could snag debris or encourage deposition of sediments with the culvert. This new length of culvert will allow an access route over the watercourse to be preserved in the west of the site, and it will provide a platform from where the inlet to the culvert can be accessed during a flood event (for inspection and clearance). For the purpose of this outline hydraulic assessment a 1.2m x 1.2m box culvert was assessed.

- A new culvert over the Tetchill Brook in the east of the site will be required to allow the new strategic link road to connect to the existing road infrastructure to the north. Due to the low-lying ground levels outside of the site, the maximum soffit is constrained to 87.23mAOD. To help offset this constraint, and for the purpose of this outline assessment, the height and width of the structure has been maximised to span as much of the channel as possible. For this outline assessment a 3.5m x 3.0m box culvert has been assessed. For context this greatly exceeds the existing soffit elevation and capacity of the 1.4m x 1.55m arch culvert located immediately upstream. This is sufficient to provide a 300mm freeboard to the 1 in 100-year+44% flood level, and a 620mm allowance for sedimentation, both of which are in accordance with CIRIA C786[16]. Note: the bottom 620mm of the culvert will be set below bed level, so the culvert will have an effective height of 2.38m (which is what has been assessed hydraulically for the purpose of this FRA).
- The new strategic road connection will also need to cross the Newnes Brook in the west of the site. Given this is a main river, this should aim to provide a minimum 600mm freeboard between the peak design flood level and the structure's soffit. It should also aim to clear span the channel and provide a soft bed to preserve hydromorphological processes. For the purpose of the hydraulic assessment, a 3.6m x 1.8m box culvert was assessed. Note: these dimensions reflect the effective flow area above channel bed, a larger culvert may be required to allow it to be sunk below bed level and provide a sedimentation allowance, in accordance with CIRIA C786.

4.7 It is recommended that the requirement for a debris screen on the inlet to the retained culvert on the Tetchill Brook is reviewed at the design stage. This may be beneficial to facilitate removal of material from the watercourse before it enters the culvert, where it could later become a blockage risk. The illustrative outline scheme has made space for a screen as well as access provision to inspect and clear the screen in the event of a flood.

4.8 An overflow flow route over the top of the retained culvert is proposed in the west of the site. This is to be located over the Tetchill Brook culvert and will provide a 'low level' exceedance route between the daylighted channel and the lowest ground level on the western boundary. This will be set at 87.40mAOD to mirror the minimum ground level on the western boundary. The minimum ground level of the development parcels will be set above this overflow level for resilience. An access road to the touring caravan site is proposed across the overflow route, and a bank of ten 450mm diameter culverts will provide hydraulic connectivity beneath this. Hydraulic modelling has suggested that this overflow would only be used in the event of a substantial blockage of a downstream culvert. This exceedance flow route will also allow any unforeseen flood water to pass through the site, such as that introduced by a possible overtopping or breach of the local canal.

[16] CIRIA, 2019. Culvert, Screen and Outfall Manual. CIRIA.

4.9 The rearranged floodplain area has been sized to preserve the existing floodplain storage volumes beneath the 1 in 100-year+33% flood level. Given the flooding mechanisms at the site (i.e.: flood water ponding in the site before draining away), floodplain conveyance is not critical. Therefore, level-for-level floodplain compensation is not critical. Instead, preservation of the available floodplain volume is of most importance in this instance. This is the same approach that was agreed with the EA as part of the previous planning permission.

4.10 The rearranged floodplain is to be relocated towards the south of the site. However, a minimum 10m offset to the canal will be provided to the top of any excavations. The connectivity between the canal overflow sluice and the Tetchill Brook will also be preserved. Locating the floodplain next to the canal means that it is in a better position to intercept any overtopping flows or breach events from the canal and direct them to the Tetchill Brook, and if necessary, the overland flow route out of the site.

4.11 These parameters are illustrated within Figure 4.1.

Hydraulic Model Verification

4.12 To verify that the proposed flood management scheme is sufficient to address the fluvial flood risk to the development, the hydraulic flood model was updated to include representation of the proposed scheme.

4.13 A strategic ground model of the site, the daylighted channel, and the rearranged floodplain was created. This is included as Appendix 4. The ground model was used to update the floodplain topography and the new channel dimensions in the hydraulic model. Hydraulic structures were added in line with the descriptions above and as illustrated within Figure 4.1.

4.14 The updated model was simulated against a number of key design flood events, and a number of theoretical blockage events on downstream culverts. These blockage events were undertaken using the 1 in 100-year +44% flood event as a precautionary measure to ensure resilience. The blockage locations are illustrated within Figure 4.2.

4.15 The results of the hydraulic modelling exercise are illustrated within Figure 4.2 with peak flood levels provided within Table 4.1, and a long section on the Tetchill Brook is provided in Figure 4.3 for reference. For visual clarity, Figure 4.2 just displays the floodplain outline for one of the blockage scenario (BL8 – a 75% blockage of the Tetchill Brook culvert downstream of the Newnes Brook confluence), but peak flood levels for all four blockage scenarios are provided within Table 4.1.

4.16 The results re-confirm what was established in 2014, that the floodplain can be successfully rearranged within the site to address the fluvial flood risk to the development areas.

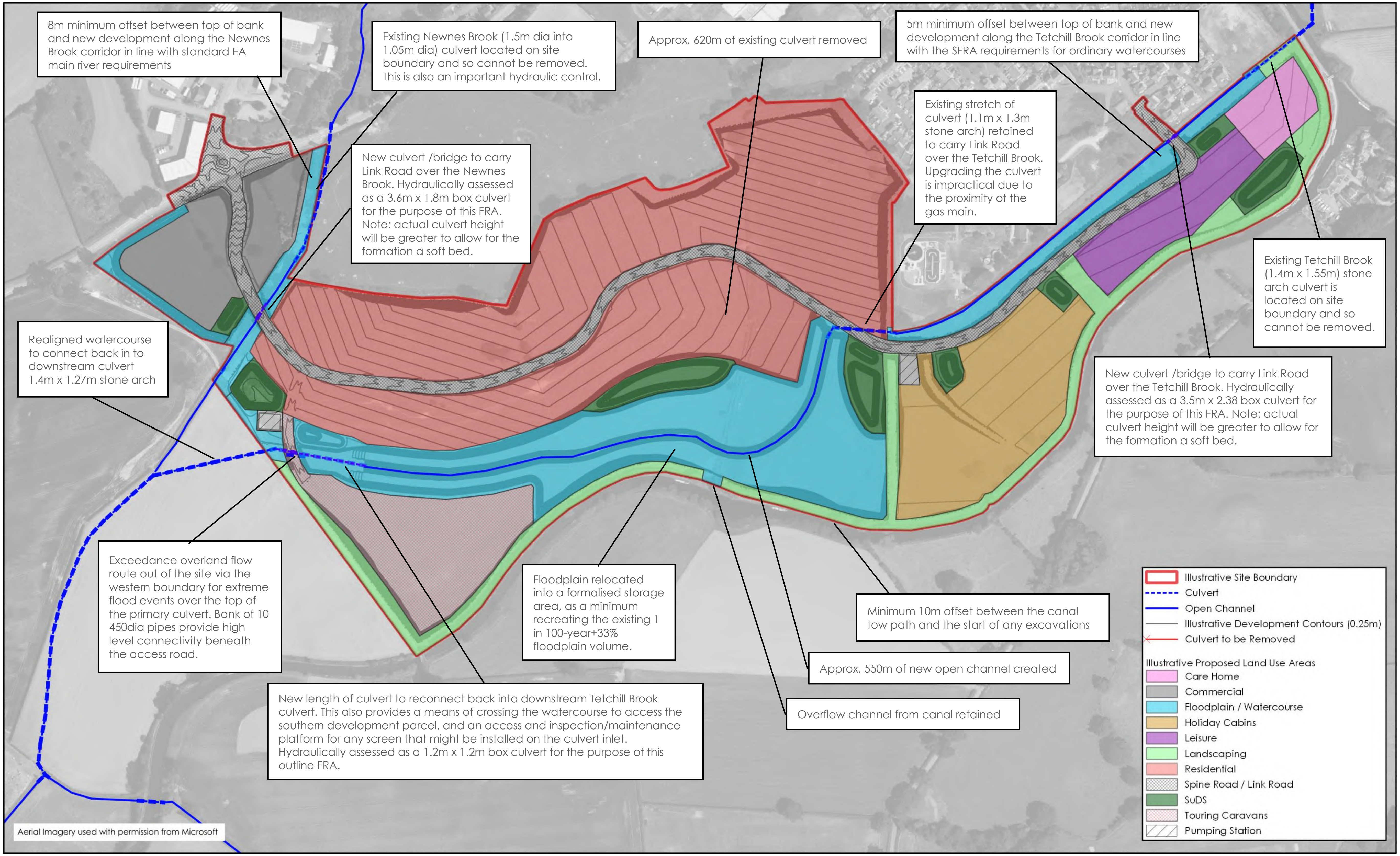

Figure 4.1: Illustrative Development Parameters

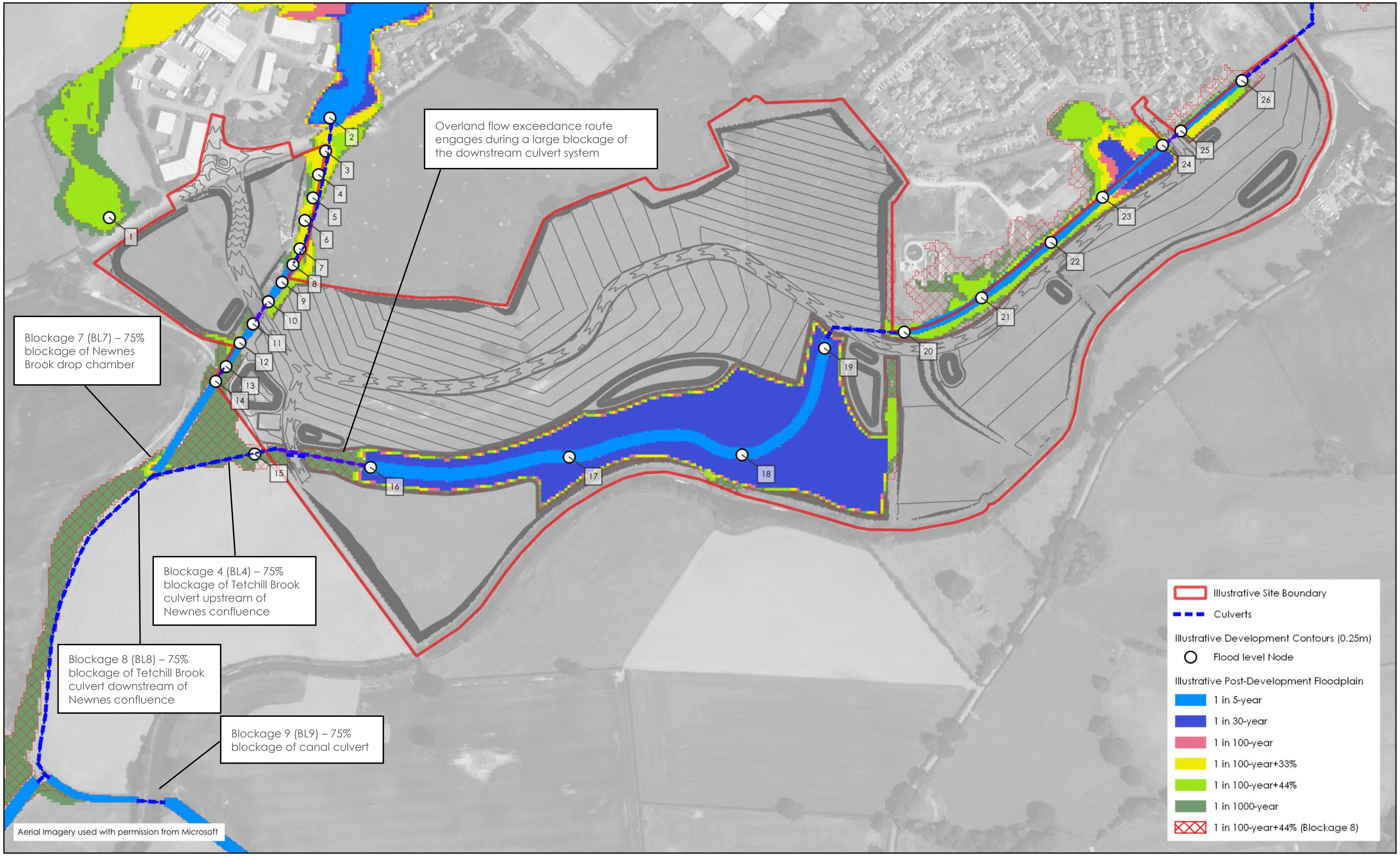

Figure 4.2: Illustrative Development Floodplain Outlines

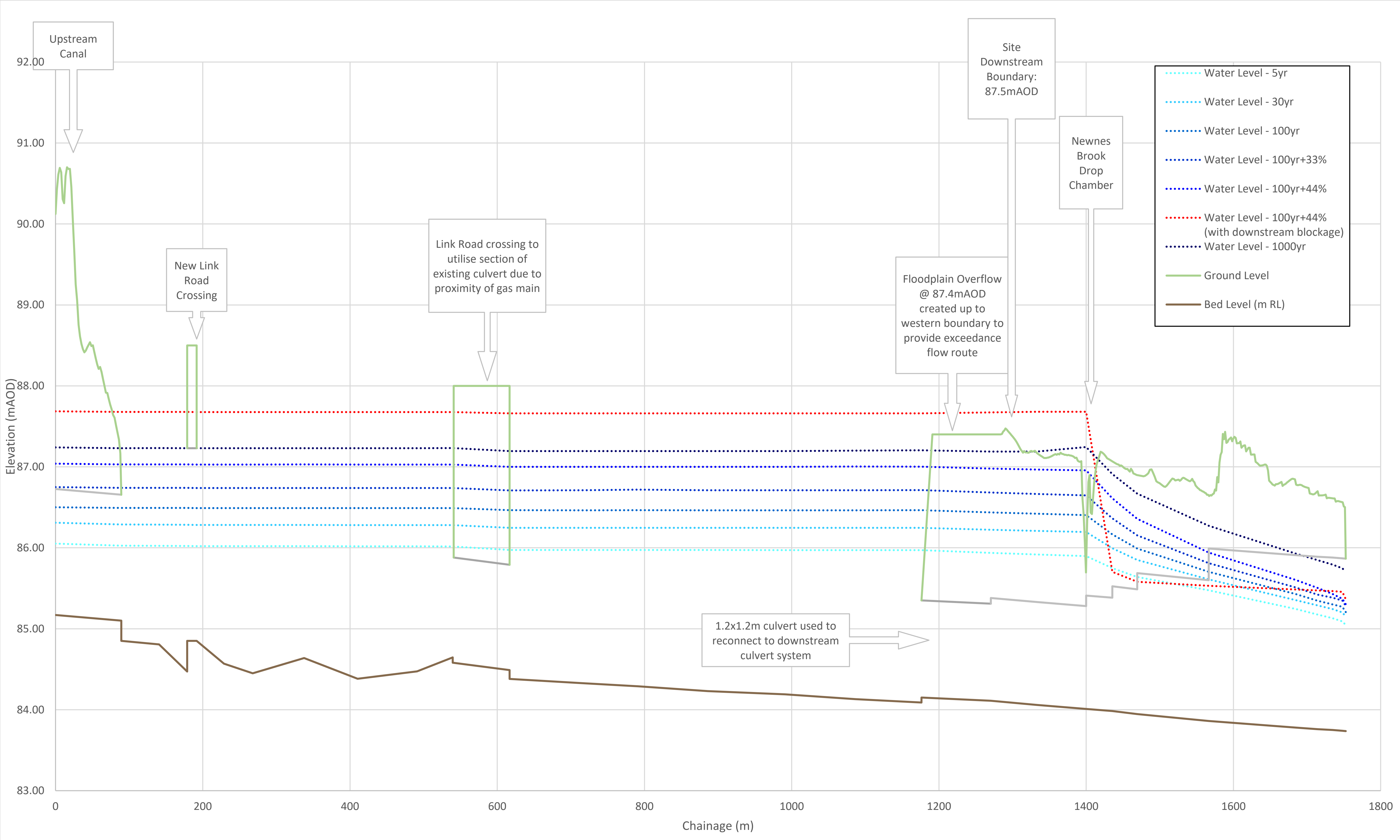

Figure 4.3: Illustrative Post-Development Long Section along the Tetchill Brook within the Vicinity of the Site

Table 4.1: Illustrative Post-Development Flood Levels

Flood Level Node	Peak Flood Level (m AOD)									
	1 in 5yr	1 in 30yr	1 in 100yr	1 in 100yr +33%	1 in 100yr +44%	1 in 1000yr	1 in 100yr +44% Blockage 4	1 in 100yr +44% Blockage 7	1 in 100yr +44% Blockage 8	1 in 100yr +44% Blockage 9
1	-	-	-	-	88.75	89.45	88.75	88.75	88.71	88.72
2	89.40	90.09	90.55	91.03	91.12	91.18	91.12	91.12	91.12	91.12
3	-	-	-	90.05	90.20	90.39	90.20	90.20	90.20	90.20
4	-	-	-	90.04	90.20	90.38	90.20	90.20	90.20	90.20
5	-	-	-	89.97	90.11	90.30	90.11	90.11	90.11	90.11
6	-	-	-	89.91	90.04	90.20	90.04	90.04	90.04	90.04
7	-	-	-	89.40	89.44	89.49	89.44	89.44	89.44	89.43
8	87.29	87.29	87.30	87.36	87.54	87.92	87.57	87.67	87.73	87.66
9	87.19	87.19	87.21	87.27	87.48	87.88	87.52	87.64	87.70	87.62
10	87.09	87.10	87.12	87.19	87.42	87.84	87.47	87.61	87.68	87.59
11	87.05	87.05	87.07	87.15	87.39	87.80	87.44	87.59	87.66	87.57
12	87.00	87.00	87.03	87.11	87.36	87.78	87.41	87.57	87.65	87.56
13	86.95	86.95	86.97	87.07	87.32	87.76	87.39	87.56	87.64	87.54
14	86.76	86.76	86.80	86.92	87.15	87.53	87.22	87.40	87.51	87.40
15	-	-	-	-	-	87.48	-	-	87.51	-

Flood Level Node	Peak Flood Level (m AOD)									
	1 in 5yr	1 in 30yr	1 in 100yr	1 in 100yr +33%	1 in 100yr +44%	1 in 1000yr	1 in 100yr +44% Blockage 4	1 in 100yr +44% Blockage 7	1 in 100yr +44% Blockage 8	1 in 100yr +44% Blockage 9
16	85.97	86.25	86.47	86.71	87.00	87.21	87.14	86.83	87.66	87.38
17	85.97	86.25	86.46	86.71	87.00	87.20	87.14	86.83	87.66	87.38
18	85.97	86.25	86.47	86.72	87.00	87.20	87.14	86.82	87.66	87.38
19	85.97	86.25	86.46	86.71	87.00	87.21	87.14	86.83	87.66	87.38
20	86.02	86.28	86.49	86.74	87.03	87.24	87.16	86.86	87.68	87.39
21	86.02	86.28	86.49	86.74	87.03	87.24	87.16	86.86	87.68	87.39
22	86.02	86.28	86.49	86.74	87.03	87.24	87.16	86.86	87.68	87.39
23	86.02	86.28	86.49	86.74	87.03	87.24	87.16	86.86	87.68	87.39
24	86.02	86.28	86.49	86.74	87.03	87.24	87.16	86.86	87.68	87.39
25	86.02	86.29	86.49	86.74	87.03	87.24	87.16	86.86	87.68	87.39
26	86.03	86.29	86.49	86.74	87.03	87.24	87.16	86.86	87.68	87.39

Sequential Arrangement

4.17 Post-development, the floodplain will have been rearranged into formalised areas alongside the newly daylighted watercourse. Only water compatible uses, such as landscaping, will be used in these areas.

4.18 The less and more vulnerable development land uses and the essential infrastructure will be located upon raised ground at a low risk of flooding.

Development Levels

4.19 The 1 in 100-year return period flood with the higher central allowance for the 2080s epoch applied (+44%) represents the required flood design event for the development given the land use and Flood Zone classification of the site:

- The finished floor levels of the more vulnerable development are to be set a minimum of 600mm above this peak flood level.
- The finished floor levels of the less vulnerable development are to be set a minimum of 300mm above this peak flood level.

4.20 For further resilience, it is recommended that as minimum all external development levels are set either above the 1 in 1000-year flood level, or 300mm above ground levels on the overland flow exceedance route out of the site, whichever is greatest.

Safe Access and Egress

4.21 The proposed Link Road/ Spine Road will provide access from the development to Ellesmere from the east of the site, and to the A495 from the west of site. The road is to adhere to the minimum levels discussed above and will therefore be at a low risk of flooding.

Floodplain Compensation

4.22 The 1 in 100-year return period flood with the central allowance for the 2080s epoch applied (+33%) represents the required design flood event for any necessary floodplain compensation provision.

4.23 The existing available flood storage on the site beneath the 1 in 100-year +33% water level has been calculated using the topographical survey as: 39,090m^3. Whereas the strategic post-development ground model tested in the hydraulic model provides: 41,175m^3. Therefore, the development offers an increase in the floodplain storage available on the site.

4.24 To verify that the proposed alterations to the watercourse and floodplain would not cause any significant detriment in the wider area and to also confirm that the volumetric approach to floodplain compensation is sufficient, the post-development hydraulic model results were compared to the baseline results. The mapped analysis maps are included as Appendix 5.

4.25 Generally, the analysis identifies a marginal betterment upstream and downstream of the site in all events up to and including the 1 in 100-year +33% return period flood. The exception to this is a short reach on the Newnes Brook located between the site and the Tetchill Brook culvert. Due to a change in the hydraulic interactions at the confluence, in-channel water levels are predicted to increase by up to 60mm. This change is contained within the channel and does not increase floodplain extents. Given the wider benefits that are offered, this minor impact is considered acceptable.

Surface Water Drainage

4.26 To mitigate the development's impact on the current runoff regime, it is proposed to incorporate surface water attenuation and storage as part of the development proposals.

4.27 Further information on the drainage approach will be provided within the accompanying SGI Consulting Engineers Drainage Report, reference C1581 20230056 Drainage Strategy.

4.28 In brief, the development will continue to discharge surface water to the current watercourse in line with the drainage hierarchy at the equivalent greenfield QBAR rate. Attenuated surface water storage will be provided in the form of SuDS detention basins in combination with below ground storage, with capacity for the 1 in 100-year storm with a 45% allowance for climate change. This will ensure that the additional impermeable surfaces and sewers that will be introduced by the development do not create a flood risk to third parties or pose a flood risk to the development itself.

4.29 Development levels should be profiled to direct surface water away from the built development and towards the nearest drainage point.

4.30 The development should be designed with exceedance in mind. The road network could be used to convey excess overland flows towards the attenuation points and overflows should be provided from the attenuation features to the local watercourses, should the design standard of the drainage be exceeded.

4.31 Finished floor levels of the development should be set above the maximum water levels within attenuation features, and also above the water levels on potential exceedance flow pathways.

Foul Water Drainage

4.32 It is proposed to drain used water from the development separately to surface water.

4.33 An application to the local sewer operator should be made at the appropriate point in the design stage to confirm point of connection and any necessary reinforcement works in the downstream network.

Land Drainage Considerations

4.34 The raising of development parcels above the floodplain will sufficiently address the risk of groundwater flooding to the development. However, there is a risk that groundwater could be encountered during the construction phase, particularly during the excavation of the new watercourse and floodplain. The ground investigations suggest that only localised perched water should be present. However, it is recommended that water levels are monitored during the construction phase and appropriate dewatering implemented where necessary.

Watercourse Inspection & Maintenance

4.35 The hydraulic assessment of the watercourses has identified that flood levels are sensitive to changes in roughness and blockages. Therefore, in line with riparian responsibilities, it is recommended that the channels and hydraulic structures within the site are regularly inspected, desilted, and maintained to ensure they remain in good operational condition.

4.36 It is recommended that the requirement for a debris screen on the inlet to the retained culvert on the Tetchill Brook is reviewed at the design stage. This may be beneficial to facilitate removal of material from the watercourse before it enters the culvert, where it could later become a blockage risk. The illustrative scheme has made space for a debris screen as well as access provision to inspect and clear the screen in the event of a flood.

4.37 If installed, the debris screen would need to be regularly inspected and cleared to prevent it from becoming a blockage risk itself.

5. CONCLUSIONS

5.1 The FRA has been produced on behalf of Burbury Investments Limited in respect of a planning application on land located to the south of Ellesmere. The planning application includes a new Link Road through the site, and reprofiling of ground levels to form future development parcels and floodplain storage. These elements will precede and facilitate a future residential-led mixed-use development of the site.

5.2 This FRA is intended to support a new planning application for the enabling earthworks and link road. However, for completeness the report appraises flood risk to the future completed development.

5.3 This report demonstrates that the proposed development is at an acceptable level of flood risk, subject to the recommended flood mitigation strategies being implemented. The mitigation measures are summarised within Table 5.1.

5.4 This FRA and the associated hydraulic model assessment are based upon a strategic ground model of the development site. Assumptions on the size and shape of the new hydraulic structures (bridges/culverts) have also been made in the absence of detailed design. It is recommended that the hydraulic performance of the watercourse, floodplain, and hydraulic structure are reassessed through the detailed design stage to ensure that their final form continues to sufficiently address flood risk.

5.5 In compliance with the requirements of NPPF, and subject to the mitigation measures proposed, the development could proceed without being subject to significant flood risk. Moreover, the development will not increase flood risk to the wider catchment area subject to suitable management of surface water runoff discharging from the site and the proposed de-culverting and floodplain rearrangement works.

Table 5.1: Summary of Flood Risk Following the Implementation of the Recommended Mitigation Measures

<table>
<tr><th>Flood Source</th><th>Flood Risk to Development Following Mitigation</th><th>Mitigation Measures</th></tr>
<tr><td>Coastal/ Tidal</td><td>None</td><td rowspan="7">- The Tetchill Brook will be partially de-culverted and the floodplain in the site rearranged into designated areas.
- The available 1 in 100-year +33% floodplain storage volume will be recreated within the designed floodplain areas.
- The more vulnerable, less vulnerable, and essential infrastructure development areas will be raised out of the floodplain.
- An overland flow route from the floodplain area to the western site boundary is to be provided to allow extreme flood and residual risk events (e.g.: culvert blockage, canal breach) to exit the site overland.
- Finished floor levels of more vulnerable development are to be set at least 600mm above the 1 in 100-year +44% flood level.
- Finished floor levels of less vulnerable development are to be set at least 300mm above the 1 in 100-year +44% flood level.
- External development levels are to be set either above the 1 in 1000-year flood level, or 300mm above ground levels on the overland flow exceedance route out of the site, whichever is greatest. This includes the link road / spine road.
- An 8m standoff is to be provided between the Newnes Brook top of bank (or edge of culvert) and any new development.
- A 5m standoff is to be provided between the Tetchill Brook top of bank (or edge of culvert) and any new development.
- The watercourse, hydraulic structures and any screens within the site are to be regularly inspected, cleared, and maintained.
- The development's impact on the current runoff regime is to be managed through the surface water attenuation and storage.
- The discharge rate from the development is to be limited to the equivalent greenfield QBAR rate.
- Attenuated storage up to the storm events up to the 1 in 100-year+45% storm event is to be provided.
- Development levels are to be profiled to direct surface water away from the built development and towards the nearest drainage point.
- Overflows should be provided from the attenuation features to the local watercourses, should the design standard of the drainage be exceeded.
- Finished floor levels of the development should be set above the maximum water levels within the surface water attenuation features, and also above the water levels on potential overland flow pathways.
- Groundwater levels are to be monitored during the construction phase and appropriate dewatering implemented where necessary.</td></tr>
<tr><td>Fluvial</td><td>Low</td></tr>
<tr><td>Pluvial / Surface Water</td><td>Low</td></tr>
<tr><td>Sewers</td><td>Low</td></tr>
<tr><td>Groundwater</td><td>Low</td></tr>
<tr><td>Canals</td><td>Low</td></tr>
<tr><td>Reservoirs and waterbodies</td><td>None</td></tr>
</table>

APPENDICES

Appendix 1: NPPF Flood risk Vulnerability and Flood Zone Compatibility

Flood Risk Vulnerability Classifications (recreated from the NPPF Planning Practise Guidance)

Vulnerability Classification	Description
Essential infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including infrastructure for electricity supply including generation, storage and distribution systems; including electricity generating power stations, grid and primary substations storage; and water treatment works that need to remain operational in times of flood. • Wind turbines. • Solar farms.
Highly Vulnerable	• Police and ambulance stations; fire stations and command centres; telecommunications installations required to be operational during flooding. • Emergency dispersal points. • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent residential use. • Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure'.)
More Vulnerable	• Hospitals • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for dwelling houses, student halls of residence, drinking establishments, nightclubs and hotels. • Non–residential uses for health services, nurseries and educational establishments. • Landfill* and sites used for waste management facilities for hazardous waste. • Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.
Less Vulnerable	• Police, ambulance and fire stations which are not required to be operational during flooding. • Buildings used for shops; financial, professional and other services; restaurants, cafes and hot food takeaways; offices; general industry, storage and distribution; non-residential institutions not included in the 'more vulnerable' class; and assembly and leisure. • Land and buildings used for agriculture and forestry. • Waste treatment (except landfill* and hazardous waste facilities). • Minerals working and processing (except for sand and gravel working). • Water treatment works which do not need to remain operational during times of flood. • Sewage treatment works, if adequate measures to control pollution and manage sewage during flooding events are in place. • Car parks.
Water-Compatible Development	• Flood control infrastructure. • Water transmission infrastructure and pumping stations. • Sewage transmission infrastructure and pumping stations. • Sand and gravel working. • Docks, marinas and wharves. • Navigation facilities. • Ministry of Defence installations. • Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. • Water-based recreation (excluding sleeping accommodation). • Lifeguard and coastguard stations. • Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. • Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

Flood Zone Compatibility (recreated from the NPPF Planning Practise Guidance)

Flood Zone	Vulnerability Classification				
	Essential infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
Flood Zone 1 (Low Probability)	Development is appropriate	Development is appropriate	Development is appropriate	Development is appropriate	Development is appropriate
Flood Zone 2 (Medium Probability)	Development is appropriate	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk • the sustainability benefits of the development to the community outweigh the flood risk.	Development is appropriate	Development is appropriate	Development is appropriate
Flood Zone 3a (High Probability)	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk the sustainability benefits of the development to the community outweigh the flood risk. Additionally, essential infrastructure should be designed and constructed to remain operational and safe in times of flood.	Development should not be permitted	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk • the sustainability benefits of the development to the community outweigh the flood risk.	Development is appropriate	Development is appropriate

BWB

Flood Zone	Vulnerability Classification				
	Essential infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
Flood Zone 3b (The Functional Floodplain)	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk • the sustainability benefits of the development to the community outweigh the flood risk. Additionally, development should be designed and constructed to: • remain operational and safe for users in times of flood; • result in no net loss of floodplain storage; • not impede water flows and not increase flood risk elsewhere.	Development should not be permitted	Development should not be permitted	Development should not be permitted	Development is appropriate if designed and constructed to: • remain operational and safe for users in times of flood; • result in no net loss of floodplain storage; • not impede water flows and not increase flood risk elsewhere.

Appendix 2: Hydraulic Model Report

A CAF GROUP COMPANY

ENVIRONMENT

Tetchill Brook
Ellesmere
Hydraulic Model Report

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ENVIRONMENT

Tetchill Brook
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GLOSSARY & NOTATION

1D – one-dimensional hydraulic model, good for representing the hydraulics of a definitive channel or flow pathway and hydraulic structure.

2D – two-dimensional hydraulic model, good for representing complex flow routing present within the floodplain.

Annual Exceedance Probability (AEP) - the probability (%) of a flood event occurring in any year.

Catchment - the land area that drains (normally naturally) to a given point on a river, drainage system or body of water.

Design flood event - magnitude of the flood adopted for the design of the whole or part of a development, usually defined in relation to the severity of the flood in terms of its return period. Typically, the 1 in 100-year return period event including an allowance for future climate change for fluvial flood events.

DTM – Digital Terrain Model

EA – Environment Agency

ESTRY - a 1D hydraulic modelling software package published by BMT.

Flood Estimation Handbook (FEH) – industry standard guidance on rainfall and river flood frequency estimation across the UK.

Floodplain - any area of land over which water flows or is stored during a flood event.

FRA – Flood Risk Assessment

Freeboard - the height of the top of a bank, floodwall or other flood defence structure, above the design water level. Freeboard can be seen as a safety margin that makes allowance for uncertainty associated with the potentially damaging effects of flood rise or wave action.

HPC - Heavily Parallelised Compute. An alternate 2D Shallow Water Equation (SWE) solver to TUFLOW Classic. Whereas TUFLOW Classic is limited to running a simulation on a single CPU core, HPC provides parallelisation of the TUFLOW model allowing modellers to run a single TUFLOW model across multiple CPU cores or GPU graphics cards.

Hydraulic Model - a mathematical (generally computer based) model of a water/sewer/storm system which is used to analyse the system's hydraulic behaviour.

LiDAR – Light Detection and Ranging aerial survey data

LLFA – Lead Local Flood Authority

M AOD – metres above Ordnance Datum

Main River - a statutory type of watercourse in England and Wales, usually larger streams and rivers. The EA can carry out maintenance, improvement or construction work on main rivers to manage flood risk as part of its duties and powers.

NRFA – National River Flow Archive

Ordinary Watercourse - a river, stream, ditch, drain, dyke, sewer (other than a public sewer) and passage through which water flows and which does not form part of a main river.

OS – Ordnance Survey

ReFH – Revitalised Flood Hydrograph rainfall-runoff hydrological model

Return period - a statistical term defining the probability of occurrence of a flood event. Thus a 1 in 50-year flood is one likely to be equalled or exceeded on average only once in a 50-year period: a flood with a 2.0% annual probability exceedance (AEP).

TUFLOW – a 2D fixed grid hydraulic modelling software package published by BMT.

UOW – Unnamed Ordinary Watercourse

Watercourse – a natural or man-made open channel for the conveyance of water.

Z-line – a break line layer in TUFLOW which can be used to reinforce linear features in the 2D model domain such as a riverbank, flood defence, or channel bed.

Z-Shape – a layer in TUFLOW which can be used to manipulate the 2D model geometry.

1. INTRODUCTION

1.1 BWB Consulting Ltd has been commissioned to prepare a hydraulic model of the Tetchill Brook through the town of Ellesmere, Shropshire, for the purpose of identifying floodplain outlines and peak flood levels between The Mere (upstream) and the downstream crossing of the Shropshire Union Canal (Llangollen Branch).

1.2 BWB Consulting first prepared a hydraulic model of the Tetchill Brook in 2014 in association with a proposed development site in the south of Ellesmere (ref: BMW-2025-TN2-RevD). The model was peer reviewed by the EA and was identified to be fit for purpose (ref: *SV/2013/107421/05*).

1.3 Over the intervening years, a number of hydrology reviews have been completed and additional datasets added to the model, keeping it up to date with the latest software and methodologies, and also extending its coverage.

1.4 This report aims to consolidate and document the updates made to the model and flood hydrology estimates and present a new set of modelled floodplain data for 2022.

The Tetchill Brook

1.5 The Tetchill Brook is an ordinary watercourse which is fed from 'The Mere', a large lake to the east of Ellesmere. It is culverted from the lake and through the town within the public surface water sewer network. A short open reach is present between the Shropshire Union Canal (Llangollen Branch) and an adjacent sewage treatment works and residential estate. The culvert through the town is comprised of a mix of 450mm diameter pipes and a stone arch culvert.

1.6 After 450m of open channel, the brook re-enters a culvert beneath arable/pasture farmland where it remains until outfalling 1.2km further downstream. The culvert here is of a stone arch construction. The culvert receives additional inflows from canal overflow drains, and land drainage.

1.7 At the outlet from this culverted reach, the Tetchill Brook is joined by a tributary watercourse draining land to the south-west of Ellesmere. The brook continues to flow in a south-easterly direction and passes beneath the Shropshire Union Canal (Llangollen Branch) for a second time. This second canal crossing represents the downstream extent of the area of interest (the study area).

1.8 Downstream of the canal, the brook flows in open channel through farmland in an easterly and then southerly direction towards the village of Tetchill, which represents the downstream extent of the model.

The Newnes Brook

1.9 The Newnes Brook is a Main River which flows from the north-west of Ellesmere in a southerly direction to the west of the town. The watercourse flows between the Ellesmere Business Park and a residential estate, and then passes beneath the A495 (Scotland

Street) within a 150m long culvert that reduces from a 1500mm diameter pipe to a 1050mm diameter pipe along its course.

1.10 The Newnes Brook re-enters open channel for approximately 260m, before it enters the Tetchill Brook culvert, via a weir arrangement/drop chamber. The weir is elevated above the soffit of the Tetchill Brook culvert, meaning that under flood conditions, flood water from the Newnes Brook can surcharge the culvert, effectively 'tide locking' the flow of water out of Ellesmere. Therefore, this downstream reach of the Newnes Brook has been included within the model extents.

1.11 A location plan of the watercourses is presented in **Figure 1.1**.

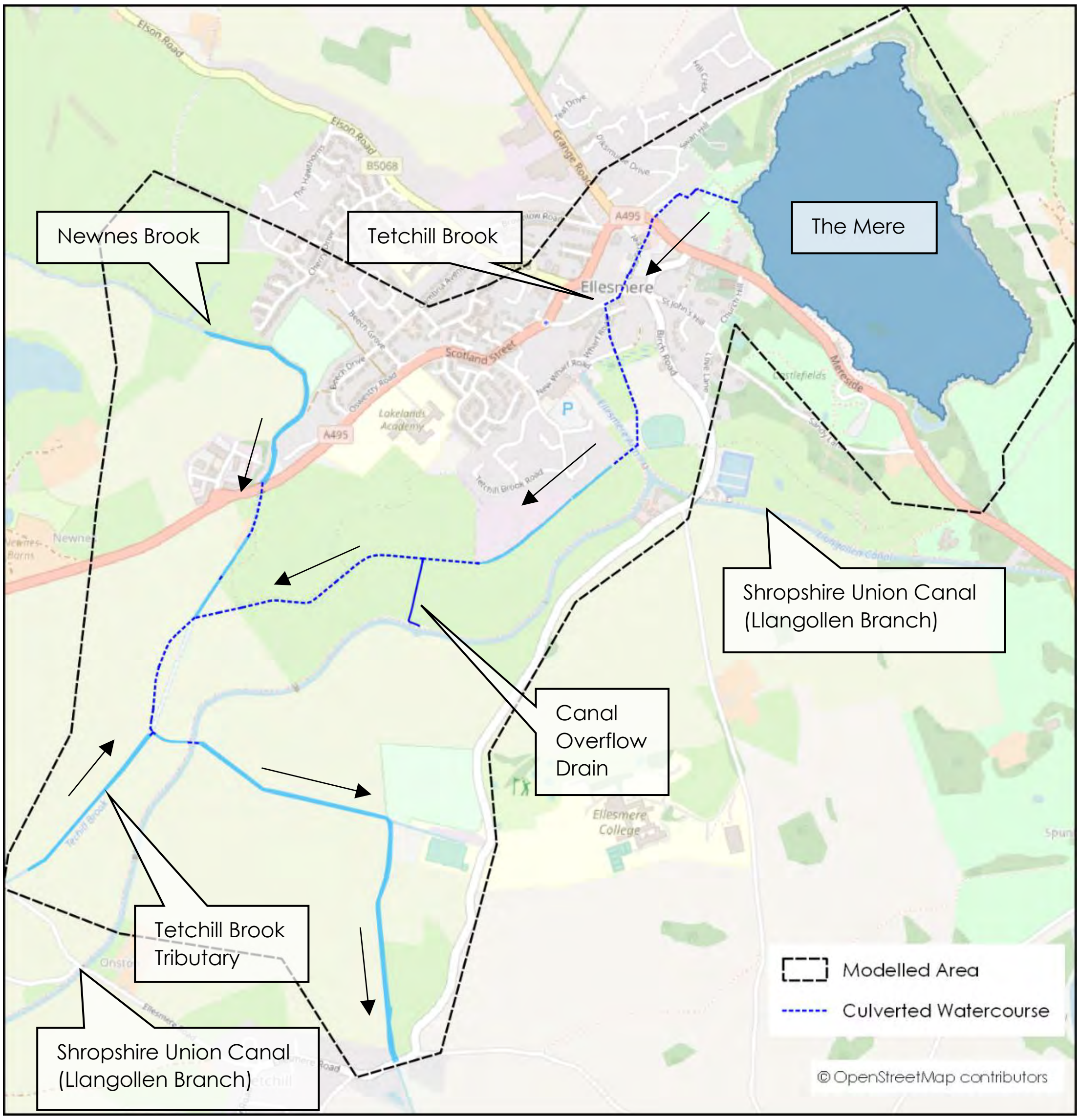

Figure 1.1 Location Plan

Generalised Topography

1.12 Topography of the area is such that the culverted reaches are required to provide hydraulic connectivity beneath the undulating topography, that would otherwise form a barrier to flows. The 'natural' flow routes appear to have been lost over time as the town and canal network developed. A generalised overview of the local topography is provided within Figure 1.2.

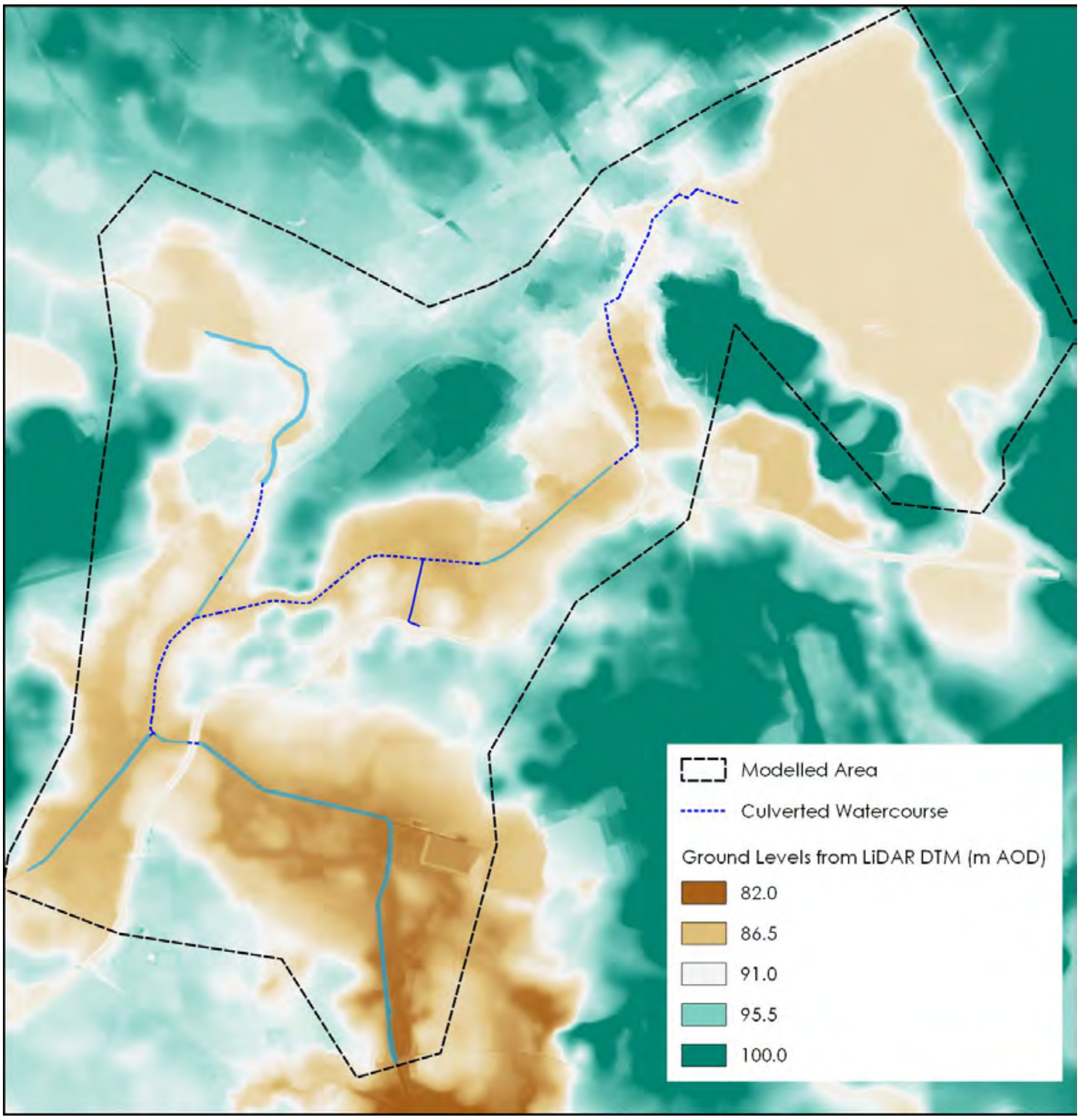

Figure 1.2: Generalised Ground Elevations

Historical Flooding Incidents

1.13 There are no known recorded incidents of flooding from the Tetchill Brook or Newnes Brook to Ellesmere.

2. SOURCES OF DATA

2.1 The data listed in Table 2.1 were used in this update. The application of the data to inform the model geometry is presented spatially within Figure 2.1.

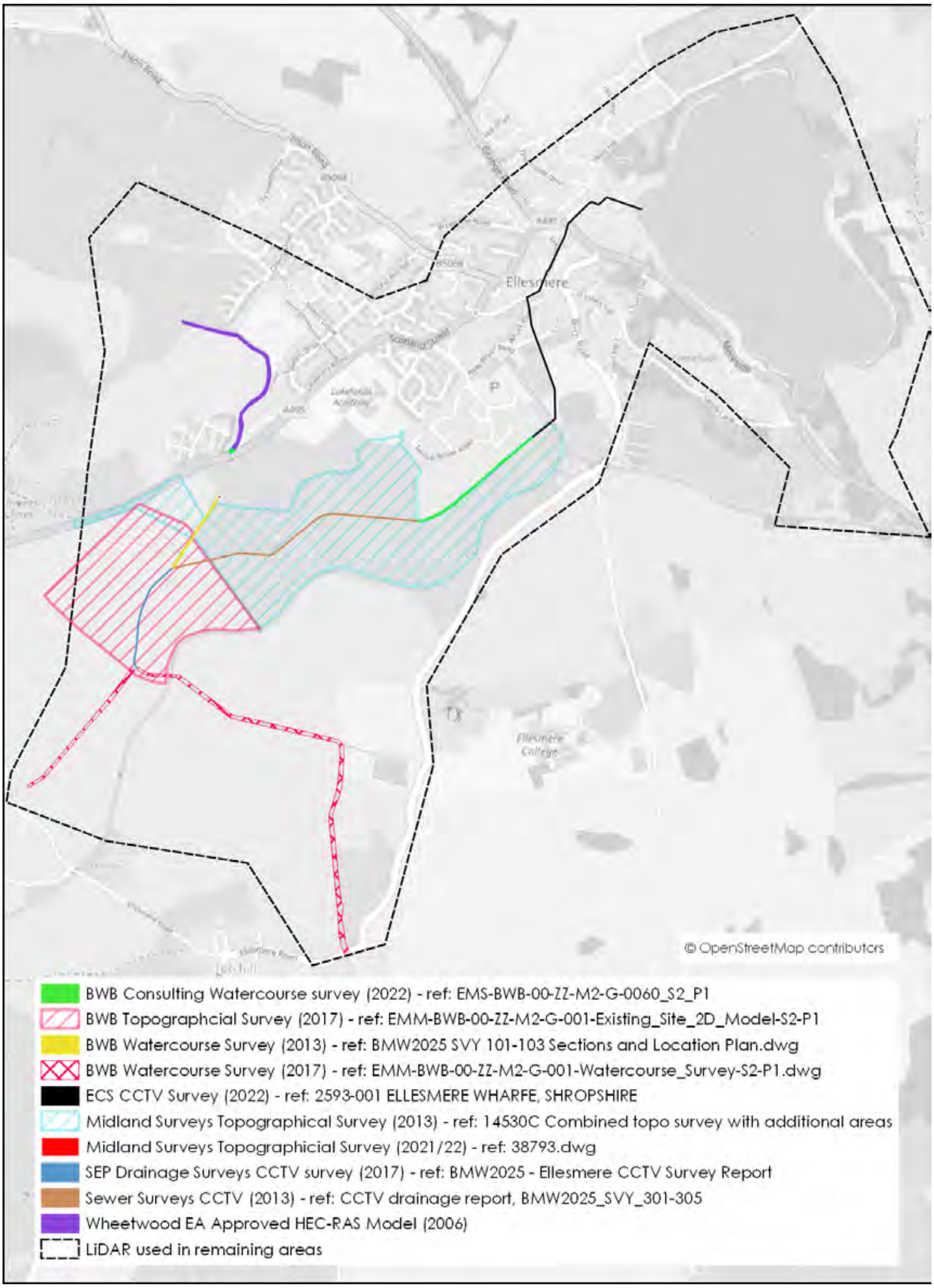

Figure 2.1: Model Data Sources

Table 2.1: Data List

Description	Data Type	Date	Ref	Source
ESTRY-TUFLOW (1D-2D) hydraulic model. Previously approved by the EA.	Digital & PDF Report	2014	BMW/2025/TN2	BWB Consulting
Historical 1D HEC-RAS Model of the Newnes Brook. Used to provide cross-section geometry data upstream of the A495	Digital & PDF Report	2006	595 FExD Final	Wheetwood Consulting Ltd
Flood Estimation of the Tetchill Brook & Newnes Brook at Ellesmere. Appendix 1	PDF Report	2022	EMM-BWB-ZZ-XX-RP-YE-002_FER	BWB Consulting
1m 2020 Composite LiDAR DTM Used as the base topography of the 2D TUFLOW Model domain	Digital	Downloaded in 2022	LiDAR_2020_SJ33ne_DTM_1m LiDAR_2020_SJ43nw_DTM_1m LiDAR_2020_SJ33se_DTM_1m LiDAR_2020_SJ43sw_DTM_1m	Environment Agency
Topographical Survey of an allocated development site in the South of Ellesmere. Used to supplement the LiDAR DTM with more detail within its coverage.	Digital ACAD	2013	14530C Combined topo survey with additional areas	Midland Surveys
Topographical survey undertaken to supplement “14530C Combined topo survey with additional areas” with additional coverage next to the Newnes Brook. Used inform the Newnes brook A495 culvert outfall size. Included as Appendix 4.	Digital ACAD	2021/22	38793	Midland Surveys
Topographical Survey of land to the west of an allocated development site in the South of Ellesmere – extends survey coverage up to the canal. Used to supplement the LiDAR DTM with more detail within its coverage. Included as Appendix 4.	Digital ACAD	2017	EMM-BWB-00-ZZ-M2-G-001-Existing_Site_2D_Model-S2-P1	BWB Consulting

Description	Data Type	Date	Ref	Source
Watercourse cross-section survey of the Newnes Brook between the A495 and the Tetchill Brook Used to replace the 1D model sections previously informed by the 2006 Wheetwood HEC-RAS model. Included as Appendix 3.	Digital ACAD	2013	BMW2025 SVY 101 – 103 Sections and Location Plan	BWB Consulting
Watercourse cross-section survey of the Tetchill Brook & Tributary Watercourse downstream of the canal. Used to extend the model coverage beyond the canal to give reassurance on potential backwater effects. Included as Appendix 3.	Digital ACAD	2017	EMM-BWB-00-ZZ-M2-G-001-Watercourse_Survey-S2-P1	BWB Consulting
Watercourse cross-section survey of the Tetchill Brook next the sewage treatment works and residential development. Also includes upstream face of A495 culvert of the Newnes Brook. Used to replace the 1D model sections previously informed by the 2006 Wheetwood HEC-RAS model Included as Appendix 3.	Digital ACAD	2022	EMS-BWB-00-ZZ-M2-G-0060_S2_P1	BWB Consulting
CCTV and trace of the Tetchill Brook culverted reach from the open reach at the sewage treatment works to the Newnes Brook. Used to set culvert geometry in hydraulic model. Summarised within Appendix 2.	Digital & PDF Report	2013	CCTV drainage report BMW2025_SVY_301-305	Sewer Surveys CCTV & BWB Consulting
CCTV and trace of the Tetchill Brook culverted reach from the Newnes Brook to the outfall. Used to set culvert geometry in hydraulic model. Summarised within Appendix 2.	Digital & PDF Report	2017	BMW2025 - Ellesmere CCTV Survey Report	SEP Drainage Surveys & BWB Consulting
CCTV and trace of culverted reach from The Mere to the open reach next to the Sewage Treatment Works. Used to set culvert geometry in hydraulic model. Summarised within Appendix 2.	Digital & PDF Report	2022	2593-001 ELLESMERE WHARFE, SHROPSHIRE	ECS CCTV Survey

Description	Data Type	Date	Ref	Source
Zoom Stack Mapping Data Used to digitise land use and roughness areas in the floodplain.	Digital GIS	March 2022	-	Ordnance Survey
Photographs and site observations. Used to determine appropriate roughness values for the river channels and hydraulic structures.	Digital	2013 - 2022	-	BWB Consulting

3. HYDROLOGY

Flood Flow Estimation

3.1 A hydrological review of the catchment was undertaken using Flood Estimation Handbook (FEH) methodologies to estimate peak flood flows and derive an appropriate hydrograph shape. This was undertaken in relation to the EA's latest guidance[1]. This assessment is documented within **Appendix 1**.

3.2 In summary, there were no hydrometric data available in the area to inform the hydrological analysis. Therefore, the industry standard FEH statistical method and Revitalised Flood Hydrograph (ReFH2.3) rainfall-runoff model were both reviewed, and a comparative analysis undertaken.

3.3 The ReFH2 method provided greater peak flows when compared to the FEH Statistical Method. However, whilst both Statistical and ReFH2 methods are considered suitable for the catchment, the final choice of peak flows for input into the model was the Statistical Method, as this is in line with the latest EA FEH Guidelines recommendation.

3.4 ReFH2 will be used to provide a hydrograph shape for the model inflows, scaled to the peak flow from the FEH Statistical Method. The division of flow is shown in **Figure 3.1**.

3.5 Flood flow estimates were derived for a range of return period events, the adopted peak flow estimates are provided within **Table 3.1**.

Table 3.1: Adopted Peak Flood Flows

Site Code	Flood peak (m^3/s) for the following return periods								
	5	10	20	30	50	75	100	200	1000
TB01 (SC01)	0.46	0.56	0.67	0.74	0.84	0.92	0.98	1.15	1.65
TB02 (SC02)	0.42	0.51	0.63	0.70	0.80	0.88	0.94	1.11	1.54
TB03 (SC03)	0.07	0.30	0.37	0.42	0.49	0.54	0.58	0.70	1.00
TB04 (SC04)	0.12	0.15	0.19	0.21	0.24	0.08	0.29	0.35	0.51
NB_DS (Newnes Brook)	3.55	4.34	5.20	5.76	6.51	6.51	7.67	9.00	12.94
TBT (Tetchill Brook Tributary)	0.28	0.34	0.40	0.45	0.50	0.50	0.59	0.69	0.99

[1] Flood Estimation Guidelines 197_08 (Environment Agency, June 2020)

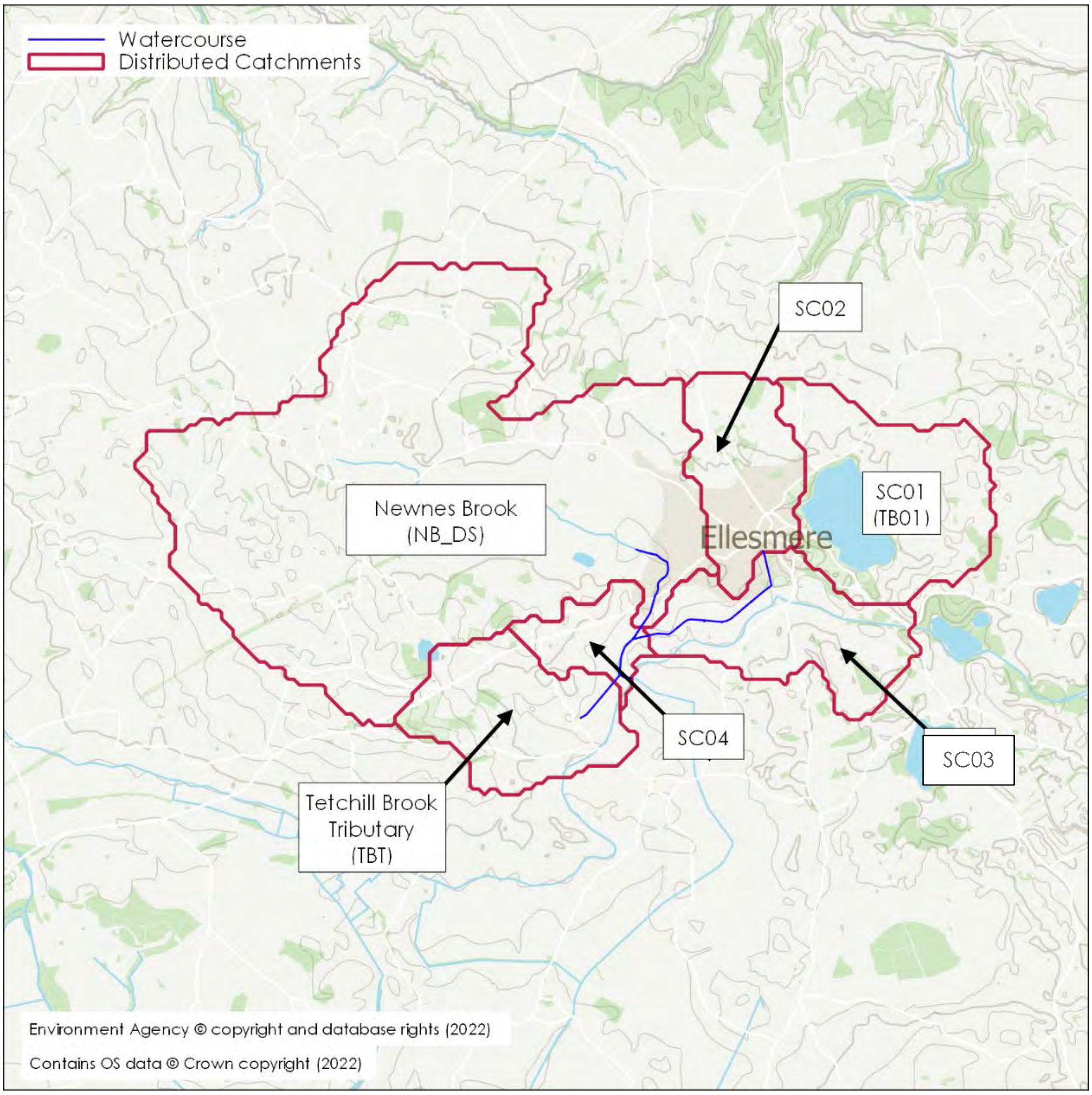

Figure 3.1: Distribution of Model Inflows

Climate Change

3.6 Predicted future change in peak river flows caused by climate change are provided by the EA within their online guidance[2], with a range of projections applied to regionalised 'River Basin Districts'. These districts are further split into 'Management Catchments'. The Tetchill Brook and Newnes Brook fall within the 'Severn Middle Shropshire' Management Catchment of the Severn River Basin District. Table 3.2 identifies the relevant peak river flow allowances.

[2] Environment Agency, Flood risk assessments: climate change allowances: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1

Table 3.2: Peak River Flow Allowance for the Severn Middle Shropshire Management Catchment in the Severn River Basin District

Allowance Category	Total potential change anticipated for the **'2020s' (2015 to 2039)**	Total potential change anticipated for the **'2050s' (2040 to 2069)**	Total potential change anticipated for the **'2080s' (2070 to 2125)**
Upper End	30%	42%	72%
Higher Central	20%	25%	44%
Central	15%	18%	33%

3.7 To estimate the potential future design floodplain under a range of scenarios, the central and higher central climate change allowance for the 2080s were applied to the 1 in 100-year flood flows.

4. THE HYDRAULIC MODEL

Software and Solver

4.1 TUFLOW version 2020-10-AC was used for all model runs which was the most recent revision at the time of simulation.

4.2 The model was simulated using TUFLOW's HPC solver to allow for efficient running of the relatively long simulation times. TUFLOWS built in 1D component, ESTRY, was used to model the 1D domain/channel.

4.3 These software packages are widely used in the United Kingdom and have been successfully benchmarked by the EA.

ESTRY: In-Channel 1D Domain

4.4 The reaches of open channel in the 2014 version of the model were originally based upon river sections extracted from the 2006 HEC-RAS model. These have mostly been replaced using the more recent and reliable surveyed cross-sections described in Section 2. The exception to this is the upper reach of the Newnes Brook which is still based upon the 2006 HEC-RAS sections. This reach is removed from the area of interest and so has not been re-surveyed, but its inclusion in the model is necessary to allow the contributing flow to be represented.

4.5 The channel sections were truncated at top-of-bank from survey data, at what would be the interface with the 2D domain. Typical channel widths are in the range of 6m-17m.

4.6 Channel roughness values were based upon photographs and observations made during site visits. The channels were observed to be relatively free flowing with mature bank vegetation and some thick scrub in places. A Manning's 'n' of between 0.040 to 0.060 was used to represent these conditions. The roughness set at each section was based upon the observed conditions at that location.

4.7 The two extended culverted reaches of the Tetchill Brook were based upon the CCTV surveys listed in Section 2. Due to access restrictions and difficulties navigating the equipment through certain sections, the culvert dimensions and inverts needed to be interpolated in places. The interpretations made are illustrated within Appendix 2.

4.8 In addition to the two extended culverted reaches, a number of shorter culverts and hydraulic structures are present in the study are these are summarised in Table 4.1.

Table 4.1: Hydraulic Structures

Structure	Details	Photograph
Mere _Outflow	NGR: 340307, 335047 Reach: Tetchill Brook Unit Type: Inlet weir to culvert system U/S IL: 88.87m AOD D/S IL: 87.77m AOD Width: 7.17m Length: - **Manning's n:** - Comments: Modelled as a 'WW' weir. Deck/ bypass modelled in the 2D domain. Geometry obtained from ECS CCTV / topographical survey.	
TetchBR1	NGR: 339856, 334245 Reach: Tetchill Brook Unit Type: Flat Deck bridge U/S IL: 84.75m AOD D/S IL: 84.57m AOD Span: 4.26m Length: 4m **Manning's n**: 0.040 Comments: Modelled as a 'BB' bridge. Deck/ bypass modelled in the 2D domain. Downstream culvert controls local water levels, this bridge structure does not influence flood levels. Geometry obtained from watercourse survey.	
A495_a/b	NGR: 339018, 334269 Reach: Newnes Brook Unit Type: Pipe Culvert U/S IL: 87.27m AOD (from watercourse survey) D/S IL: 66.57m AOD (from topographical survey) U/S Diameter: 1.50m (from watercourse survey) D/S Diameter: 1.05m (from topographical survey) Length: 150m **Manning's n:** 0.030 Comments: only the upstream inlet could be accessed during the watercourse survey. Downstream dimensions taken from the topographical survey. Structure transitions from 1.5m dia to 1.05m dia along its length. It is assumed that the larger culvert was installed beneath the A495. A linear gradient has been assumed along its length. Deck/ bypass modelled in the 2D domain	

Structure	Details	Photograph
FarmTrack	NGR: 338906, 334030 Reach: Newnes Brook Unit Type: Pipe Culvert U/S IL: 85.89m AOD D/S IL: 85.90m AOD U/S Diameter: 1.496m Length: 10m **Manning's n:** 0.030 Comments: Deck/ bypass modelled in the 2D domain. Geometry obtained from watercourse survey.	
Newnes_In	NGR: 338837, 333923 Reach: Newnes Brook Unit Type: Inlet structure to Tetchill Brook (Drop chamber) U/S IL: 85.87m AOD D/S IL: 84.01m AOD Weir Width: 1.0m x3 Opening Height: 0.856m x3 Length: - **Manning's n:** - Comments: Geometry obtained from watercourse survey. Modelled as 3 open sluice gates to represent the restrictive height on the structure. Deck/ bypass modelled in the 2D domain	
Canal _DS	NGR: 338837, 333585 Reach: Tetchill Brook Unit Type: Arch culvert beneath downstream canal U/S IL: 83.75m AOD D/S IL: 83.74m AOD Width: 1.85 Height: 3.08m Length: 25m **Manning's n:** 0.03 Comments: Geometry obtained from watercourse survey. Modelled as an irregular culvert. Deck/ bypass modelled in the 2D domain	

TUFLOW: Floodplain/2D Domain

4.9 EA 1m resolution LiDAR DTM was used as a base for the 2D representation of the channel and floodplain; this has undergone a filtering process to remove buildings and vegetation to provide a 'bare earth' ground model.

4.10 Various topographical surveys were available (as listed in Section 2) which were converted to DTM's and used to supplement the LiDAR DTM.

4.11 A 3.0m by 3.0m resolution grid was adopted for the TUFLOW model; this is more than sufficient for the mostly rural floodplain but necessary to accommodate the narrower channel widths.

4.12 Although the 3.0m cell size will pick up most of the significant topographic features, river bank levels from the watercourse survey, in combination with supplementary data from the LiDAR and topographical survey, were used to reinforce the river banks through the use of a 'Z-line' layer.

4.13 OS 'Zoom Stack' mapping was used to digitise land use areas within the floodplain and apply suitable Manning's 'n' roughness values.

4.14 Buildings, walls, and other structures were modelled at ground level in line with best practise. Buildings were given an elevated roughness value so that the structures resistance to flow is at least partially represented.

4.15 The watercourse channels were deactivated within the 2D domain, so that they were only represented by the 1D domain.

4.16 The 2D domain was digitised to meet higher ground levels on either side of the floodplain and extended to mirror the upstream and downstream extents of the 1D domain.

4.17 The 2D domain was extended upstream on the Newnes Brook to prevent excessive 'glass-walling' and allow the floodplain storage upstream of the 1D model extent to activate.

4.18 The 2D domain was extended upstream on the Tetchill Brook to encompass The Mere. A 'z shape' layer was used to lower the topography within the coverage of the lake to at least 88mAOD, and an initial water level of 88.8mAOD was applied so that the lake started the simulation completely full.

Boundary Conditions

<u>1D-2D Interface</u>

4.19 1D-2D HX (External Head) boundaries were digitised on the top of banks at the interface between the domains.

4.20 The culverted watercourses were connected to the 2D domain at manholes using 'pits' and SX (External Source (flow)) boundaries. Topographical survey has been used to derive the cover levels for the manholes. Between Dairy Grove and the cricket ground (NGR: 339994, 334596) the top of the culvert is elevated above ground levels, and the top brick is missing from the structure (see Figure 4.1). This will allow surcharging flood water to freely exit the culvert and enter the floodplain over a reach of approximately 70m. This connection was represented using a number of pits and SX boundaries.

Figure 4.1: Open Top Culvert near Dairy Grove and the Cricket Ground

Inflows

4.21 Point inflow (QT) boundaries were used to represent the fluvial inflows (from Section 3) to the top of each reach. The upstream inflow to the Tetchill Brook was applied directly to The Mere within the 2D domain, this is to allow the attenuating effects of the lake to be represented within the hydraulic model.

4.22 The inflows on the intervening catchments were distributed evenly across the relevant 1D reach.

Downstream Boundary

4.23 A fixed stage boundary set to a constant level of 81.5mAOD was used as the downstream boundary for the 1D domain. This is an arbitrary water level set to partially fill the downstream channel section. However, the downstream boundary is located 1.2km and over 2m below elevations in the area of interest, so it is not of critical importance. Sensitivity analysis on the adopted boundary is discussed in Section 7.

4.24 A 2D downstream boundary was not necessary.

Calibration/Verification

4.25 Due to the lack of documentation on previous historical instances of flooding, the model cannot be verified against historic events. A conservative approach adopted to the model build help to mitigates this limitation.

Simulation Time

4.26 Due to the slow response of The Mere, the backwater effect of the Newnes Brook and the restricted outfall on the Tetchill Brook, it was necessary to run simulations for a greater length of time than would normally be expected. The flood hydrographs generated by the recommend 7.5-hour duration storms were simulated for a duration of 70-hours. This length of time was sufficient to allow flood levels to peak and start to recede.

Model Runs

4.27 In order to achieve the study objectives, the simulations summarised in Table 4.2 were completed.

Table 4.2: Model Runs

Model Geometry	Return Periods	Comments
Baseline	1 in 5-year 1 in 10-year 1 in 20-Year 1 in 30-year 1 in 50-year 1 in 75-year 1 in 100-Year 1 in 1000-Year	Representative of 'as surveyed' present day conditions, based upon the ReFH2 recommended 7.5-hour storm event.
Climate Change	1 in 100-Year+33%CC 1 in 100-Year+44%CC	Representative of the future 1 in 100-year floodplain in the 2080s.
Sensitivity Tests		
Roughness +20%	1 in 100-Year	Floodplain, channel and structure roughness increased by 20%
Roughness -20%	1 in 100-Year	Floodplain, channel and structure roughness decreased by 20%
Downstream Boundary +1m	1 in 100-Year	1m increase in the downstream water levels downstream boundary
Downstream Boundary -1m	1 in 100-Year	1m decrease in the downstream water levels downstream boundary
Blockage Scenarios (various)	1 in 100-Year	75% blockage of critical culverts and structures

5. MODEL STABILITY AND LIMITATIONS

5.1 TUFLOW has a number of indicators available to assess the stability of a model. The following indicators were checked to ensure the model was performing as expected:

Table 5.1: Stability Review

Stability Indicator	Description	Comment
Stage and flow time series	A number of spot checks should be completed to ensure that conveyance through the channel is as expected and that both the stage and flow time series are reasonably smooth, particularly around the study area.	Flow and stage hydrographs through the model were checked and observed to be reasonable.
Negative depths	A significant number of negative depths can indicate that instabilities are present.	No negative depths were reported, and the model flux (flow in and out) did not show any significant evidence of an unstable/fluctuating 1D-2D interface.
Cumulative Mass Error	A value of +/-2% is considered acceptable.	The mass error generally remained within +/-2% for all the simulations, which is within the acceptable range.
Timestep	"dt" shows the timestep used to reach a solution over the duration of the model, as the HPC simulation used an adaptive timestep. A timestep lower than 1/10th of a TUFLOW classic timestep is considered to indicate instabilities. A TUFLOW classic timestep is typically up to 1/5 of the model grid size, so 1/10th of this value would be 0.1s (the minimum allowable timestep).	The dt remains within the expected range (i.e.: above 0.1s) for all simulations.
Courant Number (Nu values)	1.0 or greater may indicate unusually high velocities.	The Courant Number (Nu) remains below a value of 1 for all of the simulations, which is within the expected range
The Shallow Wave Celerity Number (Nc values)	Higher than 1.0 might indicate unusually high-water depths caused by a low cell elevation.	The Shallow Wave Celerity Number (Nc) peaked at just over 1 (~1.1) during the initialisation of the simulations (within the first 20 minutes of the simulation). Thereafter it remained below a value of 1, which is within the expected range.
Diffusion Number (Nd values)	0.3 or higher might suggest poor boundary setup.	The Diffusion Number (Nd) remains below a value of 0.3 for all of the simulations, which is within the expected range

Stability Indicator	Description	Comment
High Control Numbers	HCN will require timesteps to be repeated if there is an instability.	No HCN's are reported in the simulations

Limitations

5.2 The modelling exercise has made use of the available data at the time of construction and simulation. The model represents floodplain and channel conditions at the time of survey.

5.3 The model contains no formal representation of the conveyance within minor watercourses or ditches other than that captured by the model grid and within the 1D model domain.

5.4 The model includes a good coverage of river sections throughout the modelled reaches, but it was not possible to access and inspect the channel in all locations due to access restrictions and vegetation coverage.

5.5 As no hydrometric data or recorded flood levels were available, the model has not been verified or calibrated.

5.6 The 3.0m resolution of the model may negate any small-scale topographic features, although all the significant features are believed to have been captured.

5.7 The baseline floodplain levels are derived from LiDAR which has limited accuracy (+/-0.15m). However, this is considered to be sufficient for the purpose of this exercise.

5.8 The bare earth DTM does not include for the presence of walls, buildings or other structures. Buildings have been modelled at ground level with an elevated roughness level in line with best practice.

5.9 This modelling exercise has been undertaken to produce a good representation of flood risk mechanisms in and around the study site. It has not been designed to accurately map flooding in the wider catchment.

5.10 The limitations of the hydrological assessment (Appendix 1) also apply.

6. BASELINE RESULTS

6.1 The results from the baseline conditions model are mapped within Appendix 5 and are summarised below. The flood mechanisms are discussed further within the forthcoming section. The floodplain extents within the modelled domain have been summarised in Figure 6.1.

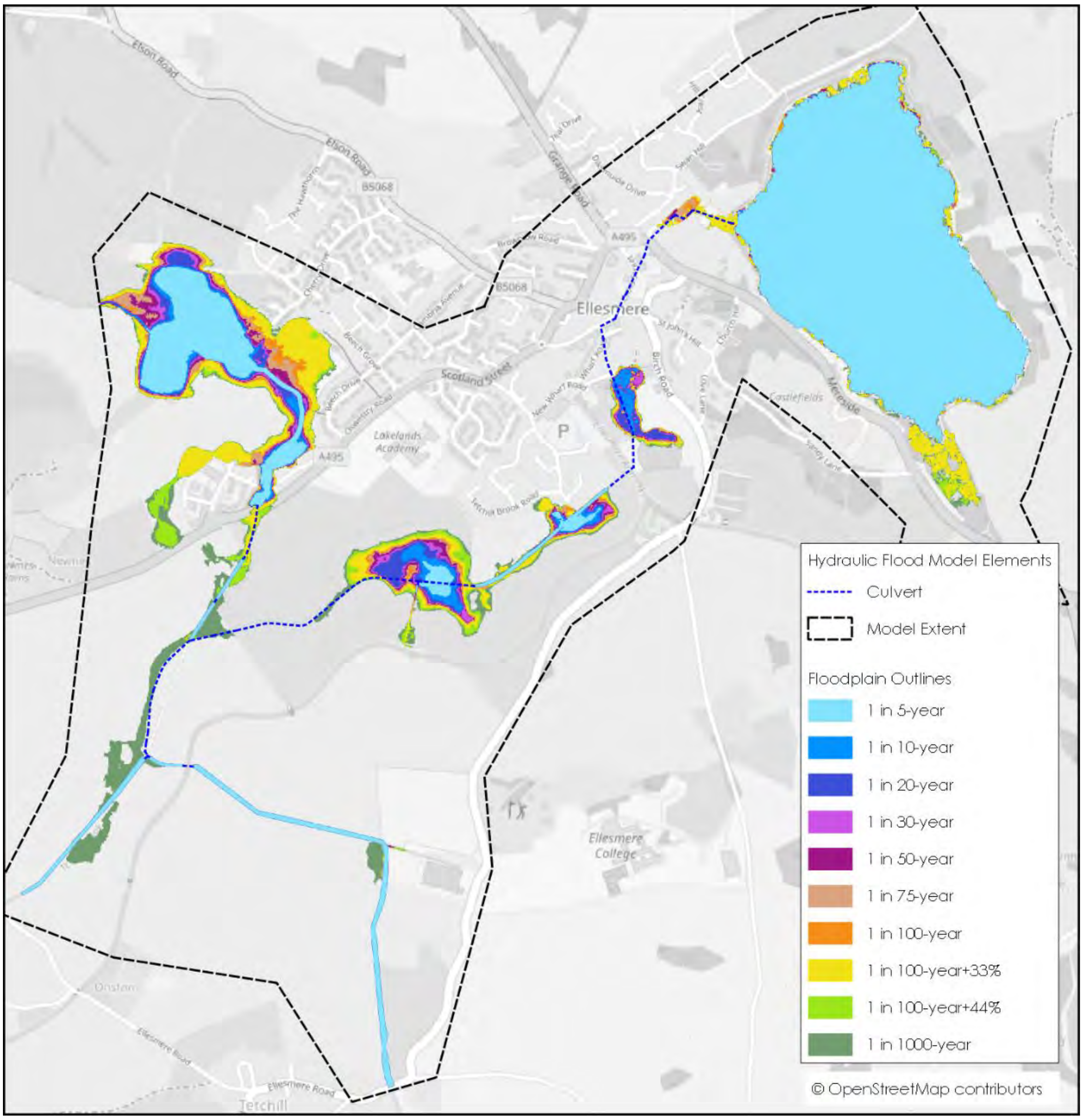

Figure 6.1: Fluvial Floodplain Extents

6.2 A long section drawn down the Tetchill Brook and Newnes Brook have been taken and are presented in Figure 6.3 and Figure 6.4. The location of the long sections are illustrated within Figure 6.2.

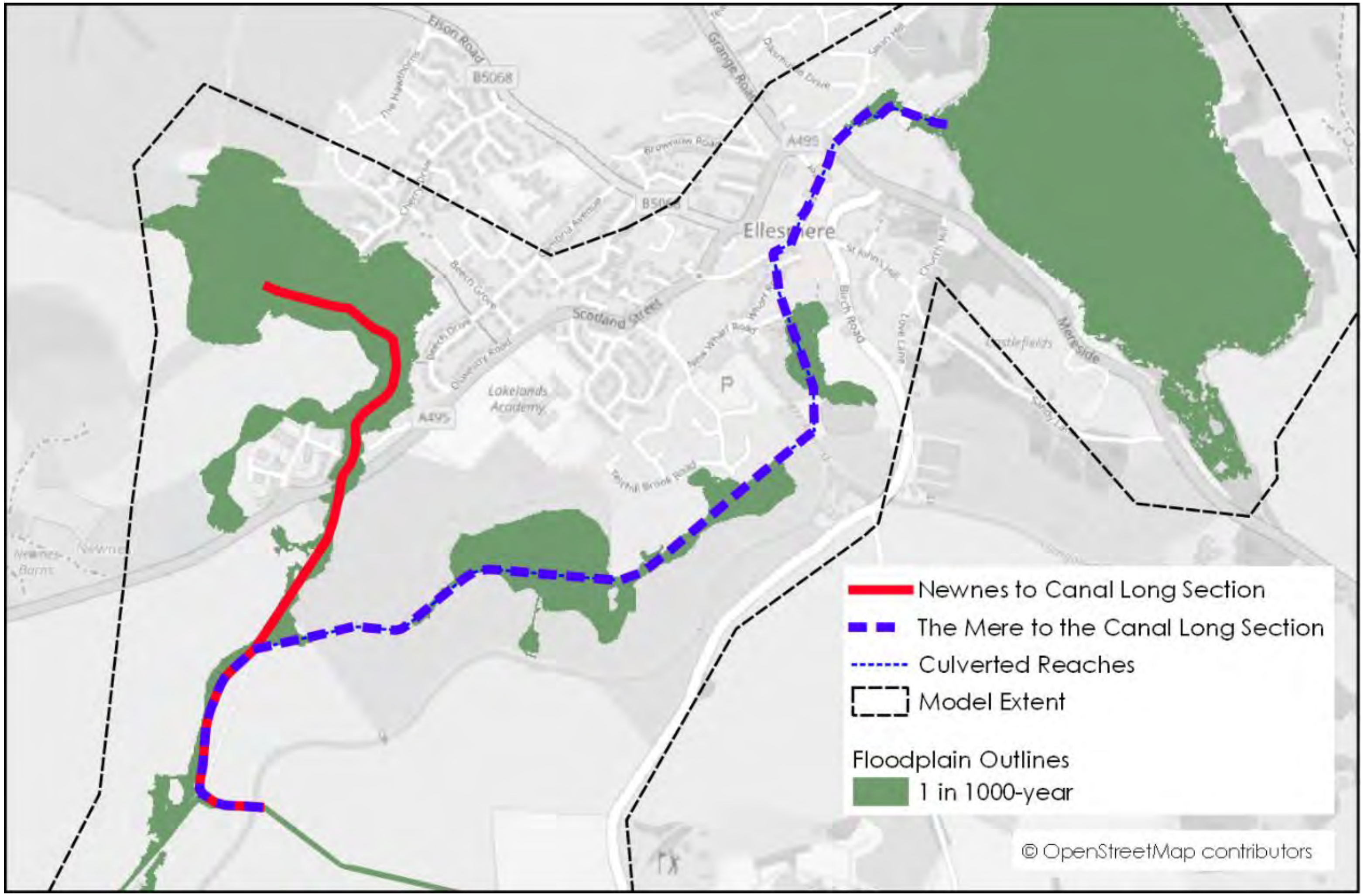

Figure 6.2: Long Profile Locations (see Figure 6.3 & 6.4)

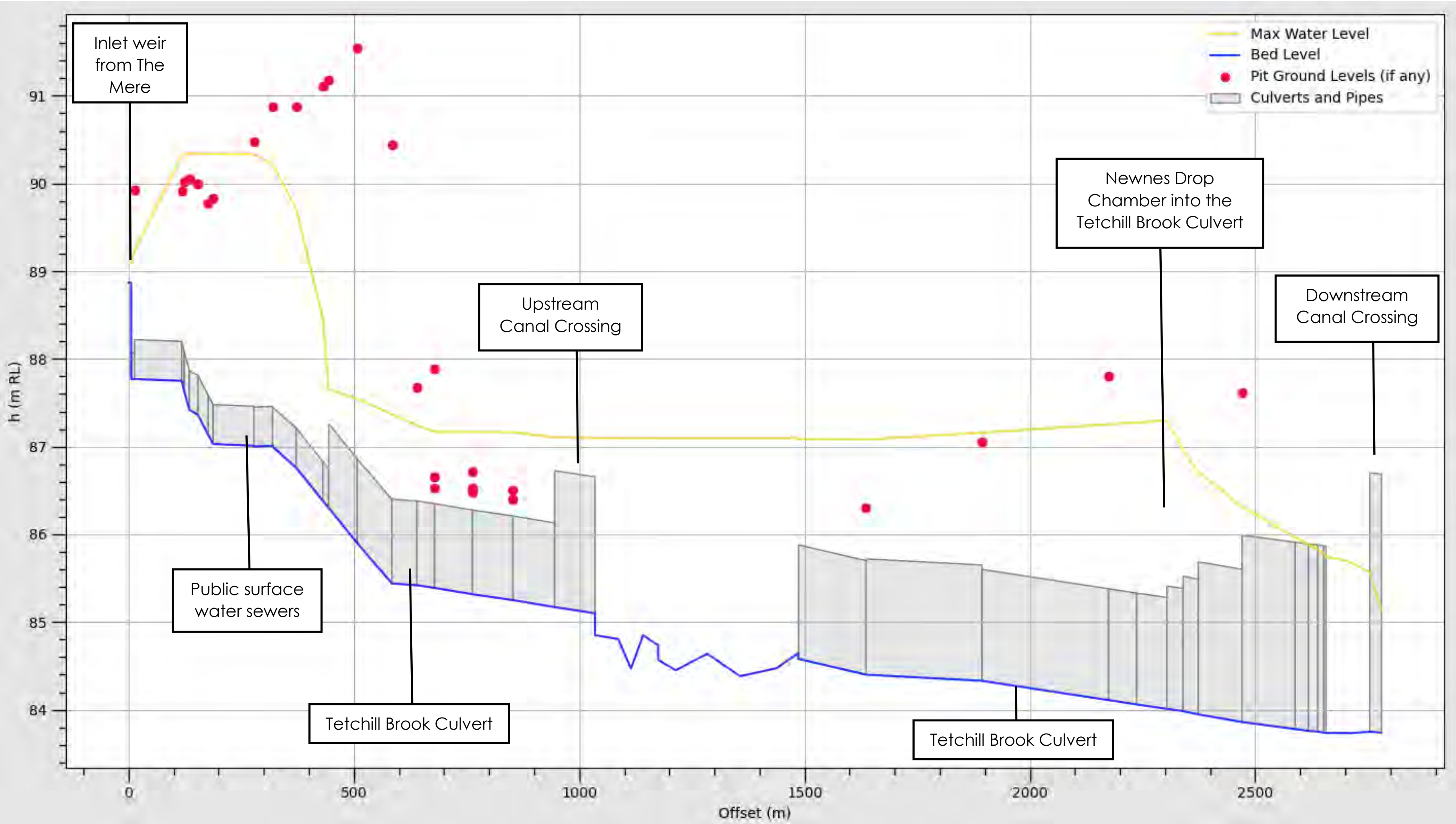

Figure 6.3: The Mere to the Canal (Tetchill Brook) Long Section (1 in 1000-Year Peak Flood Level)

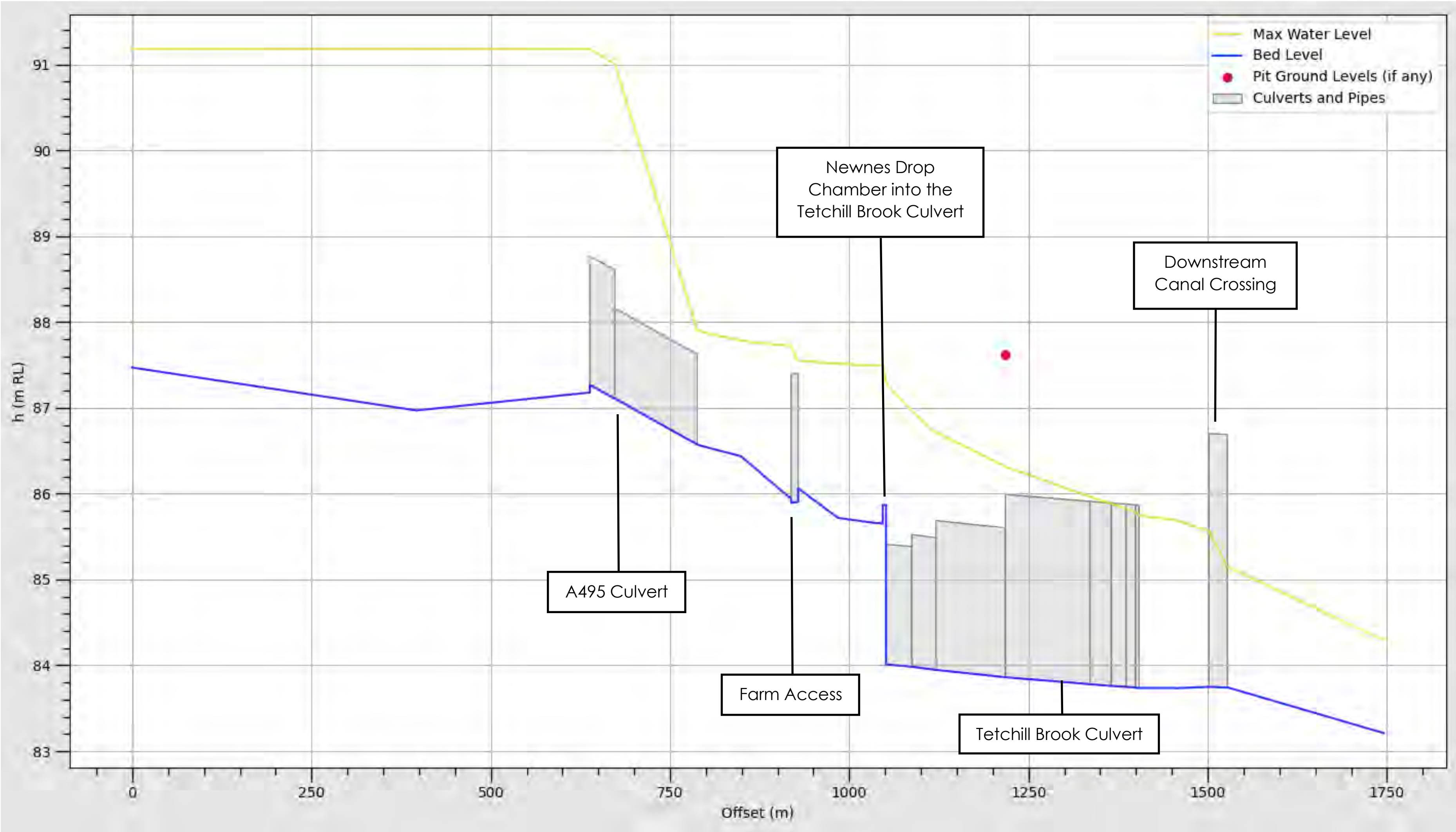

Figure 6.4: Newnes Brook to the Canal Long Section (1 in 1000-Year Peak Flood Level)

The Tetchill Brook

6.3 Analysis of the results has reconfirmed that the Newnes Brook has an important influence on the flow dynamics on the Tetchill Brook. Due to the Newnes' elevated position at the confluence with the Tetchill Brook culvert, a large ingress of water can be directed up the Tetchill Brook culvert, as well as down the culvert due to the hydraulic head difference.

6.4 This has the effect of reducing the capacity of the Tetchill Brook culvert to convey flood flows away from Ellesmere, and in the more extreme events (the 1 in 100-year+44% and the 1000-year events) flow in the culvert is actually reversed. This backwater effect can extend from the confluence with the Newnes Brook to New Dairy Grove/Wharf Road – see Figure 6.3.

6.5 Due to the elevated ground levels above the Tetchill Brook culvert, flood water entering the floodplain is confined and prevented from flowing overland. Flood water can only drain back to the watercourse once the Newnes Brook flood wave has receded, and the available capacity of the culvert has increased.

6.6 Further upstream, through the town, the flow of water is constrained by the capacity of the public sewer system, particularly in the 450mm diameter pipe network. While the manholes are predicted to surcharge under flood conditions, due to their depth, no significant flooding is predicted (see Figure 6.3), with the exception of a small area just downstream of the lake, near Talbot Gardens.

6.7 The floodplain on the Tetchill Brook upstream of the Newnes Brook confluence can be broken down into three main area:

- The Mere (Figure 6.5): The large body of water helps to attenuate the runoff upstream of Ellesmere. Pass-on flows are limited by the capacity of its outflow weir, the downstream pipe work, and the elevated ground levels in the town. The lake has the potential to overtop its banks if it receives sufficient runoff volume from the surrounding hillsides. The downstream pipe network has the potential to surcharge back into the lake and also onto road network, causing localised flooding.
- Land at Dairy Grove/New Wharf Road (Figure 6.6) – The relatively low-lying topography of this area is positioned between the high ground of the upstream town and the downstream canal embankment. The Tetchill Brook is culverted beneath the area, but it essentially has unrestricted hydraulic connectivity with the floodplain due to a number of holes in the top on the culvert. Inflows into this area are restricted by the limited capacity of the sewer network. Pass-on flows are restricted by the capacity of the culvert beneath the canal, which is influenced by the backwater effect from the Newnes Brook. No overland flows out of the floodplain can occur due to the elevated topography surrounding the area. Therefore, runoff from the upstream town surcharges onto the floodplain from within the culvert, where it pools until downstream flood levels recede and it can drain back into the culvert.

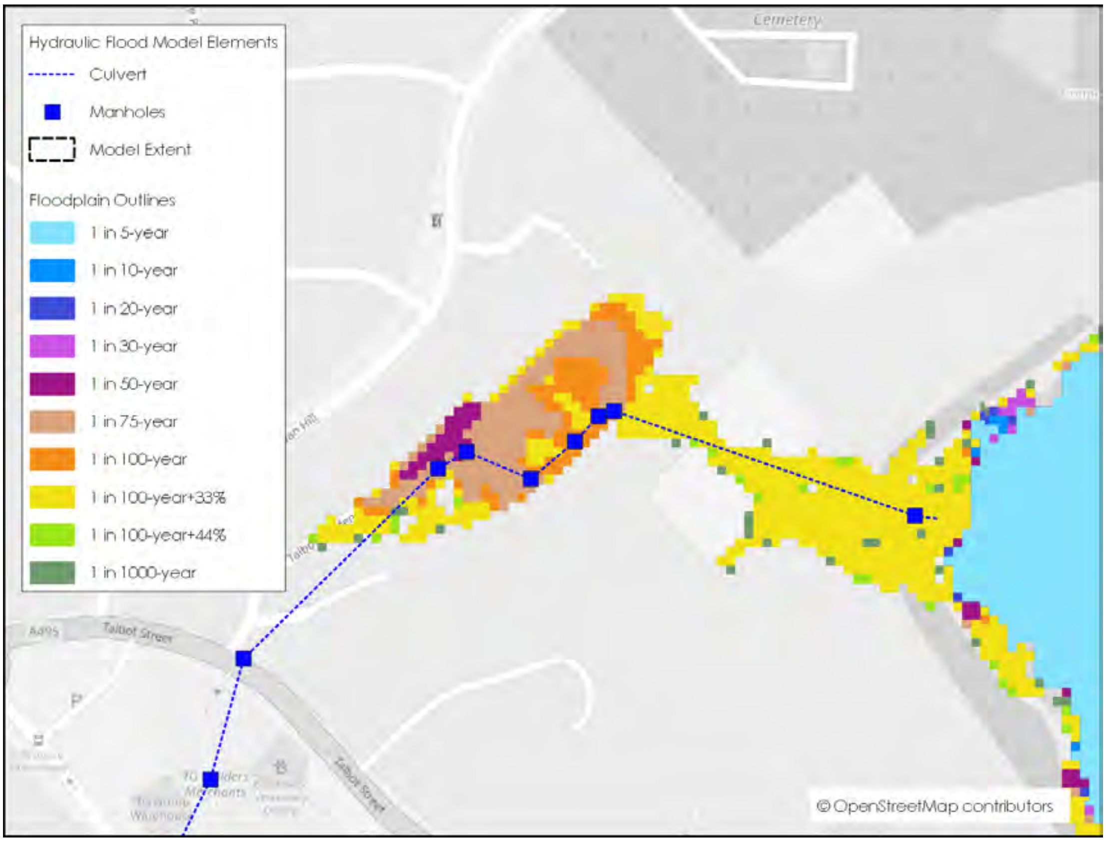

Figure 6.5: Floodplain at The Mere

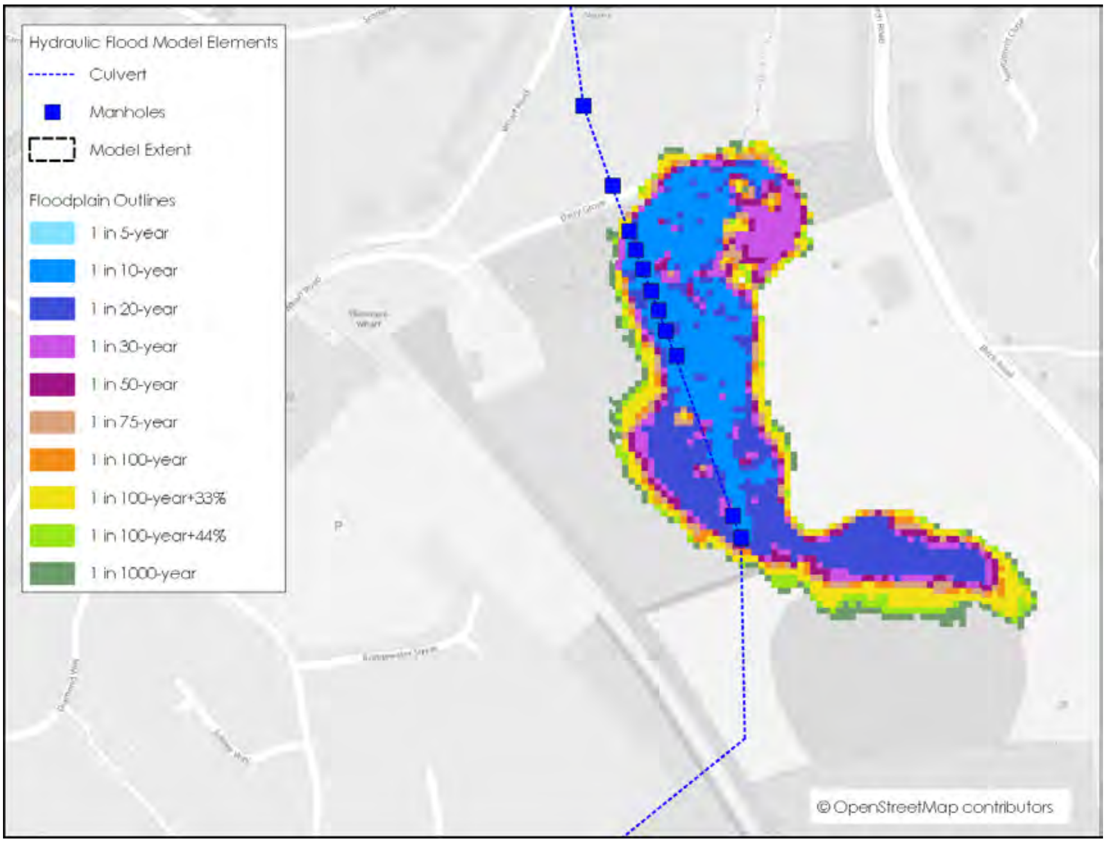

Figure 6.6: Floodplain at Dairy Grove/New Wharf Road

- Land to the South of Ellesmere (Figure 6.7) - The relatively low-lying topography of this area is positioned between the high ground of the upstream canal embankment and the downstream topography, which rises to meet the Newnes Brook. The Tetchill Brook is culverted beneath some of the area, but there is an open reach present immediately downstream of the canal. Pass-on flows are restricted by the capacity of the downstream culvert, and the influence of the backwater effect from the Newnes Brook. No overland flows out of the floodplain can occur due to the surrounding elevated topography. Therefore, the combined flood water from the surcharging Newnes Brook and Tetchill Brook accumulate on the floodplain until downstream flood levels recede and it can drain back to the culvert/channel.

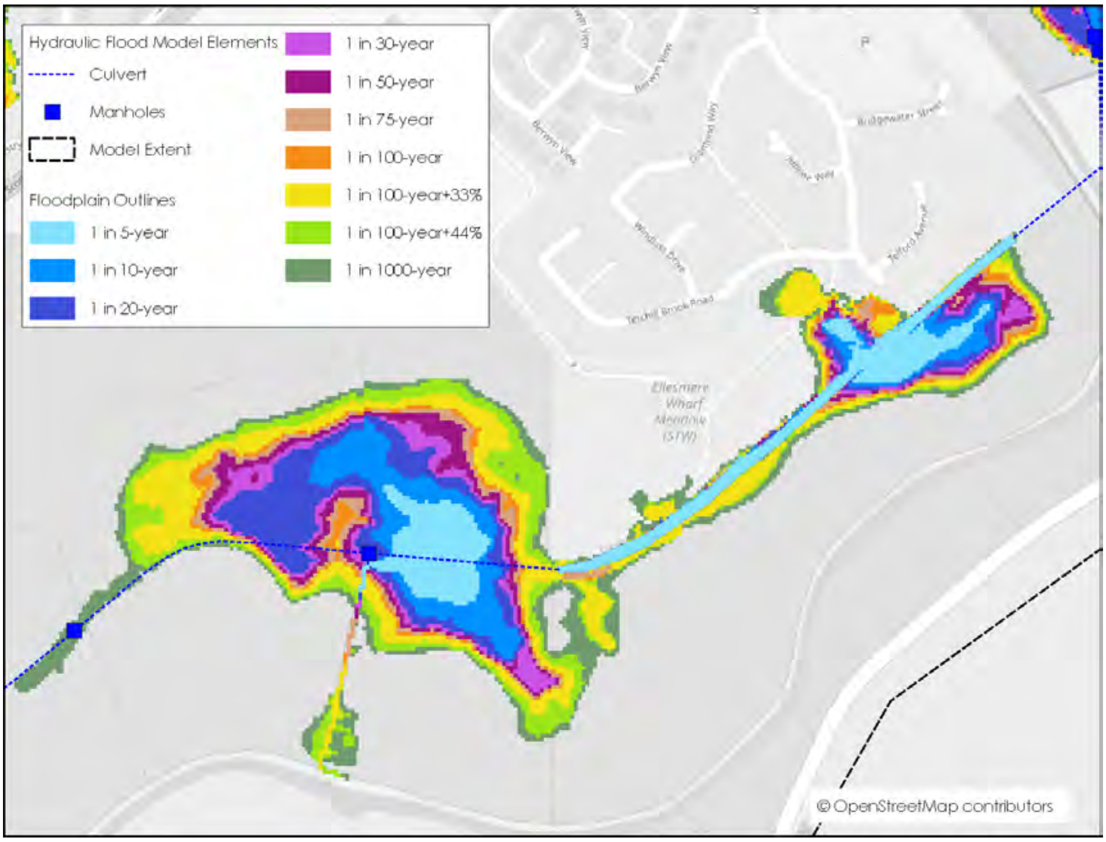

Figure 6.7: Floodplain in the South of Ellesmere

Newnes Brook

6.8 On the Newnes Brook, the culvert beneath the A495 (1.5m diameter pipe reducing to a 1.05m diameter pipe at its outfall) is shown to be a significant restriction on flood flows. Flood water is attenuated upstream, leading to widespread flooding – this is illustrated within Figure 6.4. This reduces the peak flow reaching the Tetchill Brook, but it also extends the hydrograph peak and extends the time that the Tetchill Brook is surcharged from the Newnes Brook.

6.9 At the 1 in 100-year+33%, 1 in 100-year+44%, and 1 1in 1000-year flood events, flood levels are sufficient to generate a flow route that overtops the A495 and re-enters the channel downstream of the A495 culvert – this is illustrated within Figure 6.8.

6.10 Between the A495 and Tetchill Brook culvert, the Newnes Brook floodplain remains relatively close to the channel. Out of bank flooding is only predicted in the 1 in 100-year+33%, 1 in 100-year+44%, and 1 1in 1000-year flood events, and this is due to the additional flood water overtopping the A495.

6.11 At the confluence with the Tetchill Brook, flood water enters the culvert via the drop chamber. When the capacity of this structure is exceeded, flood water ponds within the upstream channel, this creates the head difference that generates the backwater effect on the upstream Tetchill Brook. At the 1 in 1000-year event, flood levels are sufficient to overtop bank levels on the Newnes Brook, and flow downstream over the top of the culvert, where it re-enters open channel immediately upstream of the canal.

6.12 Downstream of the main culverted reach the watercourse is joined by a tributary. The channel here is narrow and deep and the floodplain generally remains within channel, except for the 1 in 1000-year event which generates some localised out of bank flooding.

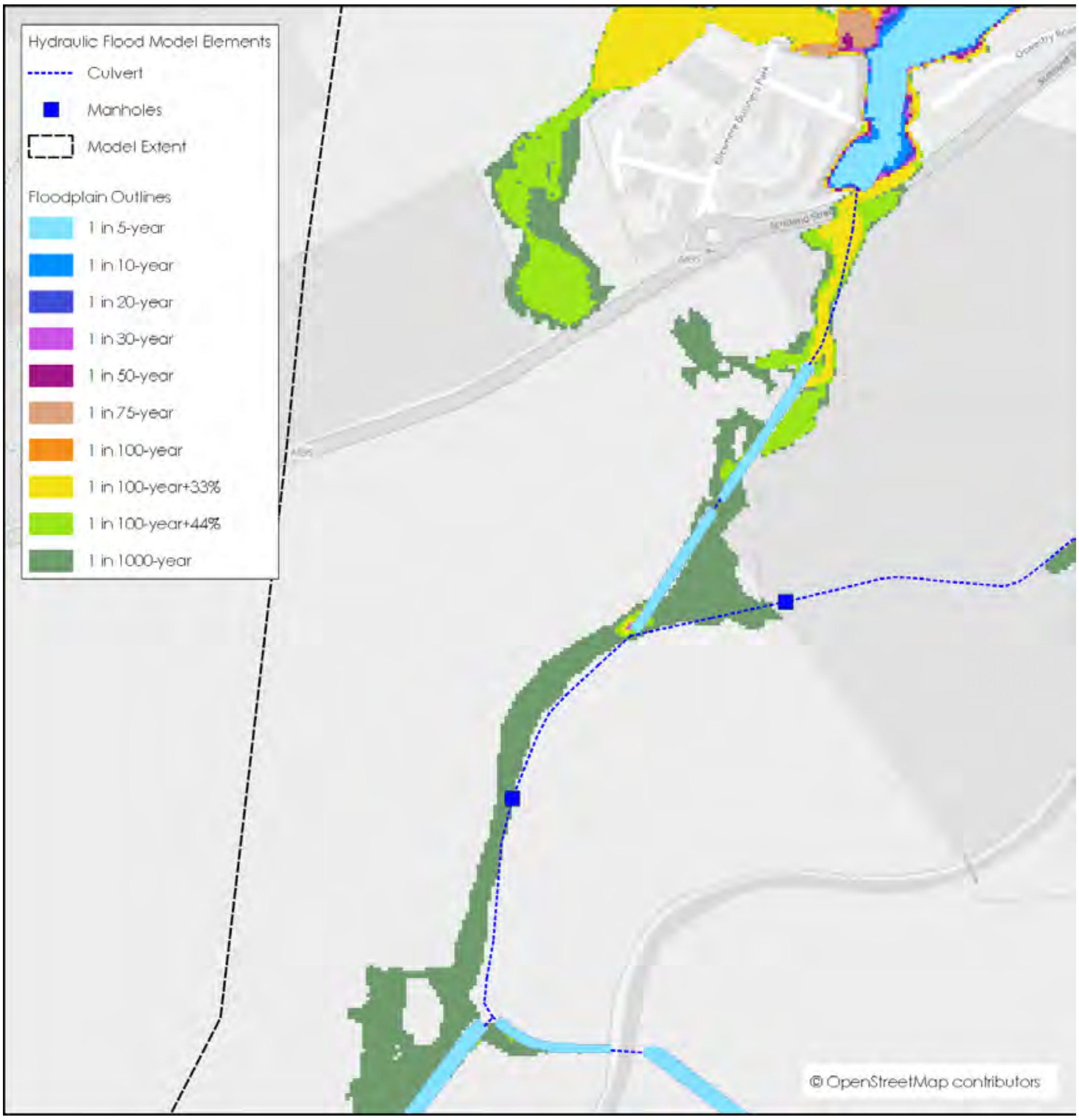

Figure 6.8: Newnes Brook Floodplain

7. SENSITIVITY TESTING

7.1 Sensitivity tests have been carried out at the 1 in 100-year return period event to identify the model's sensitivity to certain hydraulic parameters, and the potential residual flood risk posed by blockages of key structures.

7.2 The difference in peak water level and floodplain extents between the sensitivity test scenarios and the 1 in 100-year baseline event are mapped in **Appendix 6**.

7.3 The changes in peak water levels at specific locations, as shown in **Figure 7.1**, are tabulated within **Table 7.1**.

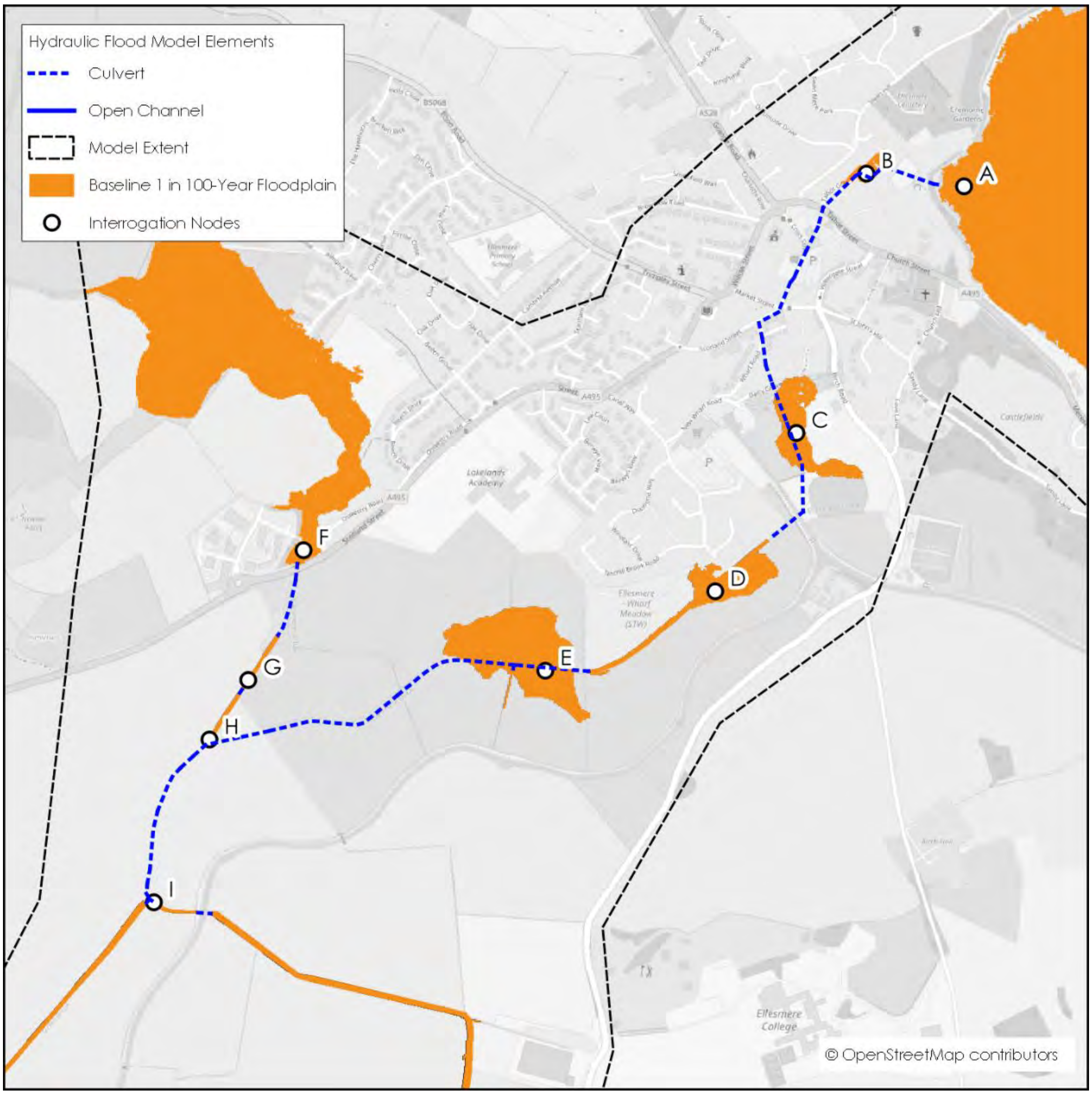

Figure 7.1: Sensitivity Test Node Locations

Table 7.1: Sensitivity Test Comparisons

Node	Baseline 1 in 100-Year Flood Level (m AOD)	Change in Peak Flood level from Baseline 1 in 100-Year Event (m)					
		Downstream boundary +1m	Downstream boundary -1m	Flow +20%	Flow -20%	Roughness +20%	Roughness -20%
A	88.97	0.00	0.00	0.04	-0.03	0.01	-0.01
B	90.10	0.00	0.00	0.19	-	0.16	-
C	86.85	0.00	0.00	0.12	-0.15	0.06	-0.08
D	86.74	0.00	0.00	0.11	-0.14	0.05	-0.06
E	86.49	0.00	0.00	0.13	-0.17	0.06	-0.08
F	90.56	0.00	0.00	0.32	-0.37	0.10	-0.10
G	86.50	0.00	0.00	0.11	-0.13	0.01	0.01
H	87.01	0.00	0.00	0.04	-0.04	-0.02	0.07
I	85.21	0.00	0.00	0.06	-0.06	0.03	0.00

Downstream Boundary

7.4 The modelled downstream boundary is a HT boundary set to partially fill the downstream channel. This is located 1.2km downstream of the area of interest. The downstream boundary was varied by 1m, with comparisons to the baseline results showeing no variation in water level within the area of interest (i.e.: The Tetchill Brook between The Mere and the downstream crossing of the Shropshire Union Canal).

7.5 This gives confidence that the downstream boundary has been located sufficiently far away from the study area as to not influence the results.

Flows

7.6 The 1 in 100-year flows were increased and decreased by 20% and compared against the baseline 1 in 100-year event to identify the extent of changes.

7.7 A comparison of peak flood levels against the original 1 in 100-year results confirms that a lower flood flow will return lower peak flood levels, and a higher flow will return higher peak flood levels.

7.8 The relatively large change in water level brought about by the variation in flow (between 0.32m and -0.37m) further demonstrates how the restrictive hydraulic structures are a significant influence on flood levels through Ellesmere. It would be expected for the change in peak flood level to be large upstream of the elevated embankments, as flood water is artificially influenced by the attenuating effects of the hydraulic structures.

Roughness

7.9 The modelled roughness coefficients were determined from OS mapping, site observations and photographs. Increasing and decreasing the roughness values in the channel and structures, as well as in the floodplain, will test how seasonal variation in vegetation growth, and the condition of hydraulic structures, may affect flood levels.

7.10 A 20% increase in Manning's n roughness coefficient, representative of a period without maintenance or a period of vegetation growth, generally leads to increased peak flood levels across the model domain. The increase in levels ranges from between 0.01m to 0.16m. This is to be expected given that an increase in roughness values across the floodplain would be associated with greater frictional forces against the flow of water. Subsequently, more flood water would likely be attenuated by hydraulic structures under these conditions.

7.11 The exception to this rule is at point H (the Newnes Brook upstream of the inlet to the Tetchill Brook culvert). Flood levels here are predicted to decrease slightly (-0.02m) due to the greater attenuation of flows that occurs upstream at the A495 culvert and within the Tetchill Brook culvert.

7.12 A 20% decrease in Manning's n roughness coefficient, representative of a period with maintenance or vegetation decline, generally leads to reduced peak flood levels across the model domain. The decrease in levels ranges from between 0.01m to 0.10m. This is to be expected, as the reduced roughness will increase the conveyance of the culverts and channel, allowing water to flow more freely through the system.

7.13 The exception to this rule is at points G and H (the Newnes Brook upstream of the inlet to the Tetchill Brook culvert). Flood levels here are predicted to increase slightly (0.01m to 0.07m) due to the reduced attenuation of flows that occurs upstream at the A495 culvert.

Blockage Scenarios

7.14 Due to the culverted system often being the only form of flood conveyance in Ellesmere, a number of blockage scenarios were assessed to identify the potential residual flood risk should the condition of one be detrimentally affected. A relatively large blockage of 75% was chosen for each scenario. The location of each blockage scenario is identified within Figure 7.2, with the change in water level tabulated in Table 7.2.

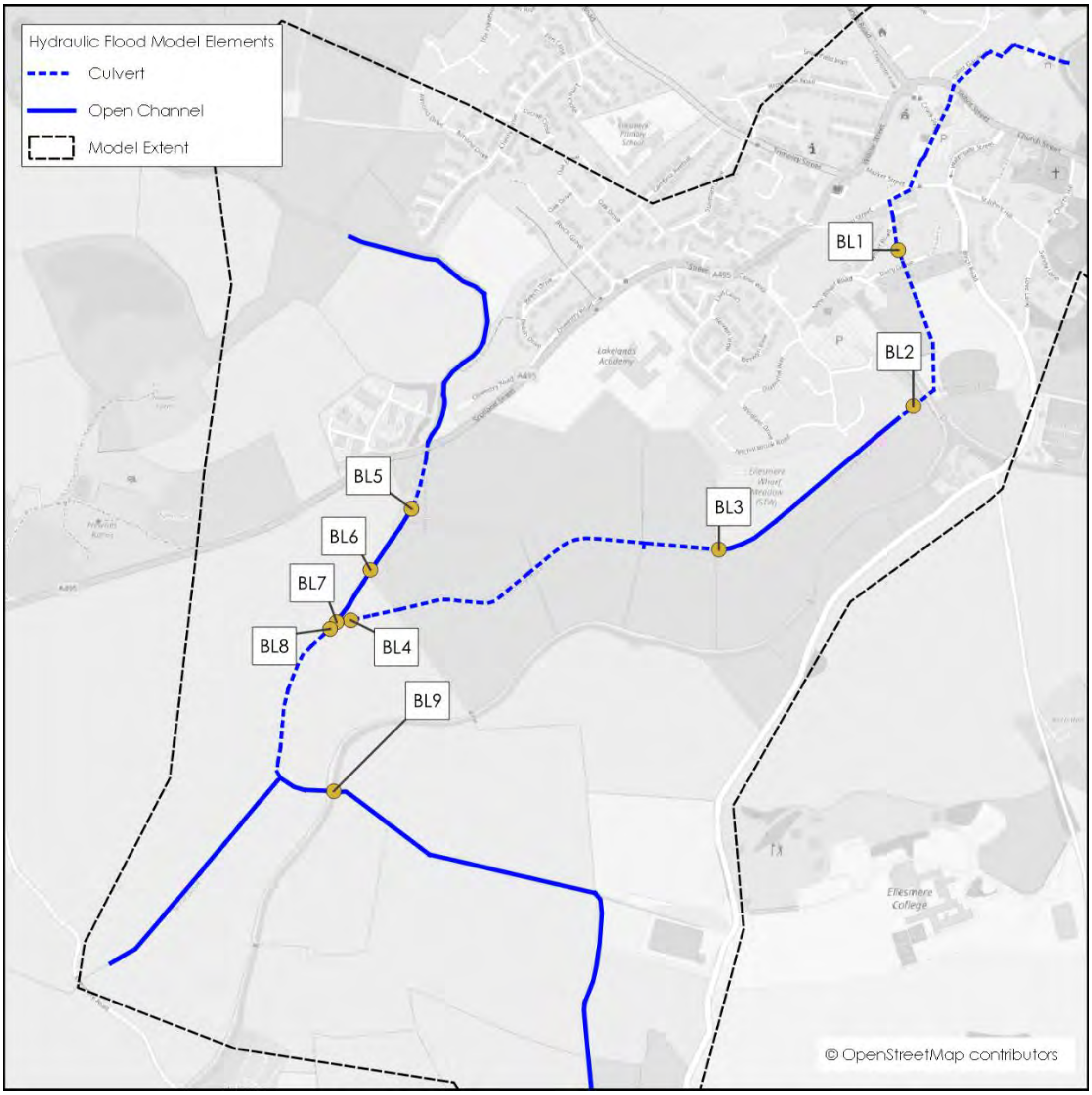

Figure 7.2: Blockage Scenario Locations

Table 7.2: Blockage Scenario Comparisons

Node	Baseline 1 in 100-Year Flood Level (m AOD)	Change in Peak Flood level from Baseline 1 in 100-Year Event (m)								
		BL1	BL2	BL3	BL4	BL5	BL6	BL7	BL8	BL9
A	88.97	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
B	90.10	0.14	0.02	0.00	0.00	-0.01	0.00	0.00	0.02	0.01
C	86.85	-0.03	0.31	0.07	0.08	-0.16	-0.01	-0.01	0.45	0.30
D	86.74	-0.02	-0.18	0.10	0.11	-0.25	0.00	0.00	0.54	0.38
E	86.49	-0.03	-0.04	-0.02	0.20	-0.54	0.00	0.00	0.79	0.63
F	90.56	0.00	0.00	0.00	0.00	0.56	0.01	0.00	0.01	0.00

Node	Baseline 1 in 100-Year Flood Level (m AOD)	Change in Peak Flood level from Baseline 1 in 100-Year Event (m)								
		BL1	BL2	BL3	BL4	BL5	BL6	BL7	BL8	BL9
G	86.50	-0.01	-0.06	-0.05	-0.11	-0.27	0.01	0.60	0.89	0.62
H	87.01	0.00	0.00	0.00	0.00	-0.21	0.63	0.22	0.47	0.22
I	85.21	0.00	-0.02	-0.02	-0.05	-0.21	0.00	0.00	-0.16	1.11

BL1 – Culvert upstream of Dairy Grove/New Wharf Road

7.15 A 75% blockage of this 1.16x0.91m stone arch culvert results in an increase in water levels within the upstream sewer system. Flood levels at point B (Talbot Garden) are increase by 0.14m. This scenario also results in flood water emerging from the manhole immediately upstream of the blockage, which flows overland and into the nearby floodplain. Downstream flood levels are reduced slightly (-0.03m) due to the increased upstream attenuation.

BL2 – Culvert Beneath Canal

7.16 A 75% blockage of this 1.40x1.56m stone arch culvert increases flood levels at point B (0.02) and point C (0.31m). No additional flood routes are generated. Downstream flood levels are reduced slightly (-0.18m to -0.06m) due to the increased upstream attenuation.

BL3 – Inlet to Tetchill Brook Culvert

7.17 A 75% blockage of this 1.1m diameter inlet structure increases flood levels at Point C (0.01) and Point D (0.10m). Flood water is able to pass the blockage by entering the downstream culvert via a secondary entrance serving the canal overflow channel. Downstream flood levels are reduced slightly (-0.05m to -0.02m) due to the increased upstream attenuation.

BL4 – Tetchill Brook Culvert Upstream of Newnes Brook Confluence

7.18 A 75% blockage of this 1.40x1.27m stone arch culvert increases flood levels at point C (0.08), point D (0.11m) and point E (0.20m). No additional flood routes are generated. Downstream flood levels are reduced (-0.16m to -0.05m) due to the increased upstream attenuation.

BL5 – Newnes Brook A495 Culvert

7.19 A 75% blockage of this 1.05m diameter outfall pipe significantly increases upstream flood levels at point F (0.56m). The increase in flood levels generates a new flood route over the A495. Downstream flood levels are reduced due to the additional upstream attenuation (-0.54m to -0.01m). The reduction is particularly large on the Tetchill Brook upstream of the Newnes Brook confluence, which again highlights the influence that the Newnes Brook has on this reach.

BL6 – Newnes Brook Farm Access Culvert

7.20 A 75% blockage of this 1.50m diameter outfall pipe significantly increases upstream flood levels at point H (0.63m). The increase in flood levels generates a new flood route which bypasses the structures. Downstream flood levels are not significantly affected.

BL7 – Newnes Brook Inlet to Tetchill Brook Culvert

7.21 A 75% blockage on the inlet structure increases flood levels with the upstream reach point G (0.60m) and point H (0.22m). No new flood routes are formed. Downstream flood levels are not significantly affected.

BL8 – Tetchill Brook Culvert Downstream of Newnes Brook Confluence

7.22 A 75% blockage of this 1.40x1.40m stone arch culvert increases flood levels on the Tetchill Brook (back to The Mere) and on the Newnes Brook (up to the A495). The blockage causes new overland flow routes to form from the Newnes Brook to the downstream open channel. With the exception of points B, F and I, this blockage has the most significant impact of all the scenarios tested. Downstream flood levels are reduced (-0.16m) due to the increased upstream attenuation.

BL9 – Culvert Beneath Canal

7.23 A 75% blockage of this 1.85x3.08m stone arch culvert could also increase flood levels on the Tetchill Brook back to The Mere and on the Newnes Brook up to the A495, although the predicted impacts are less server than BL8. The blockage causes large new areas of floodplain to form on the Tributary watercourse. Downstream flood levels are reduced due to the increased upstream attenuation.

Summary

7.24 Blockages of the assessed structures would result in relatively large increases to upstream flood levels. Of particular note was the Tetchill Brook culvert downstream of the Newnes Brook confluence, and the downstream canal culvert, where a potential blockage could have widespread impacts on the upstream Tetchill Brook and Newnes Brook.

8. SUMMARY & RECOMMENDATIONS

8.1 Please note that this conclusion should be read in conjunction with the study limitations and assumptions in Section 5.

8.2 BWB Consulting Ltd has been commissioned to prepare a hydraulic model of the Tetchill Brook though the town of Ellesmere, Shropshire, for the purpose of identifying floodplain outlines and peak flood levels between The Mere and the downstream crossing of the Shropshire Union Canal (Llangollen Branch).

8.3 BWB Consulting first prepared a hydraulic model of the Tetchill Brook in 2014 in association with a proposed development site in the south of Ellesmere. The model was peer reviewed by the EA and was identified to be fit for purpose (ref: SV/2013/107421/05).

8.4 Over the intervening years a number of hydrology reviews have been completed and additional datasets added to the model, keeping it up to date with the latest software and methodologies, and also extending its coverage. This report consolidates and documents the updates made to the model and flood hydrology estimates and presents a new set of modelled floodplain data for 2022.

8.5 The modelling has reconfirmed that flooding on the Tetchill Brook is influenced by the capacity of the extensive culverted reaches and hydraulic structures, the undulating topography, as well as the backwater effect from the Newnes Brook.

8.6 Analysis has shown that the Tetchill Brook is sensitive to flows, roughness, and blockages, which is a result of the artificial influence of the numerous culverts and the undulating topography.

8.7 For many reaches, the only available flow pathway is through a culvert, with no alternative or overland flow route available. Therefore, the potential blockage of a culvert could have far reaching impacts on upstream flood levels. Regular inspection and maintenance of culverts and hydraulic structures should be undertaken to ensure they remain in good condition and are free flowing.

8.8 Uncertainty on the estimated flood flows could be reduced through a period of flow monitoring, but the timescales of such an undertaking do not align with the timescales of this project.

APPENDICES

Appendix 1: Hydrological Assessment

A CAF GROUP COMPANY

ENVIRONMENT

Tetchill Brook
Ellesmere
Flow Estimation Record

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BWB

ENVIRONMENT

Tetchill Brook
Ellesmere
Flow Estimation Record

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BWB

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CONTENTS

1. METHOD STATEMENT

Overview of requirements

1.1 Updated flow estimates were required for input into a hydraulic model of the Tetchhill Brook. The hydraulic model extends between The Mere and the crossing of the Llangollen Canal.

1.2 The watercourse to be modelled is shown in Figure 1.1.

Figure 1.1: Site Location Plan

Previous Assessments

1.3 A hydrological assessment of the Tetchill Brook was previously undertaken in 2014. The assessment used the ReFH (Revitalised Flood Hydrograph). This method provided the worst-case estimates.

1.4 The previous hydrological assessment used a distributed approach in which the Tetchill Brook catchment was split up and design flows routed through each sub-catchment. The Tetchill Brook was divided into three sub-catchments to distribute inflows through the model, as follows:

- The first sub-catchment (SC01) is delimited by The Mere. The outfall from the Mere into the local surface water sewer network is limited by a 300mm diameter pipe. The capacity of this restriction was previously calculated as $0.20m^3/s$. Therefore, the contributing flows from this sub-catchment were set at $0.20m^3/s$ for all return periods.
- The second sub-catchment (SC02) was located between The Mere and the upstream boundary of the Ellesmere Marina development site.
- The third sub-catchment (SC03) included the land between upstream and downstream boundaries of the Ellesmere Marina development site.

1.5 The Newnes Brook catchment was also assessed at its confluence with the Tetchill Brook.

1.6 In 2018, the hydraulic model was extended downstream to capture any potential hydraulic interactions further downstream. As such, two additional subcatchments were added.

- A fourth sub-catchment (SC04) of Tetchill Brook located between the downstream boundary of the Ellesmere Marina site and the canal,
- The Tetchill Brook Tributary watercourse.

1.7 Flood flows for these two additional catchments were assessed in 2018 using the same ReFH procedure.

1.8 A schematic showing the distributed catchments for the 2018 modelling is provided in Figure 1.2.

1.9 Since the above assessments, there have been changes in hydrological assessment methods and updates to software such as WINFAP and ReFH2. There has also been the release of a new catchment descriptor – BFIHOST19, which replaces BFIHOST. Furthermore, additional years of data are now available in the NRFA Peak Flow Dataset which will affect statistical analysis results. The latest version of the EA Flood Estimation Guidelines also provides further clarity on methodologies.

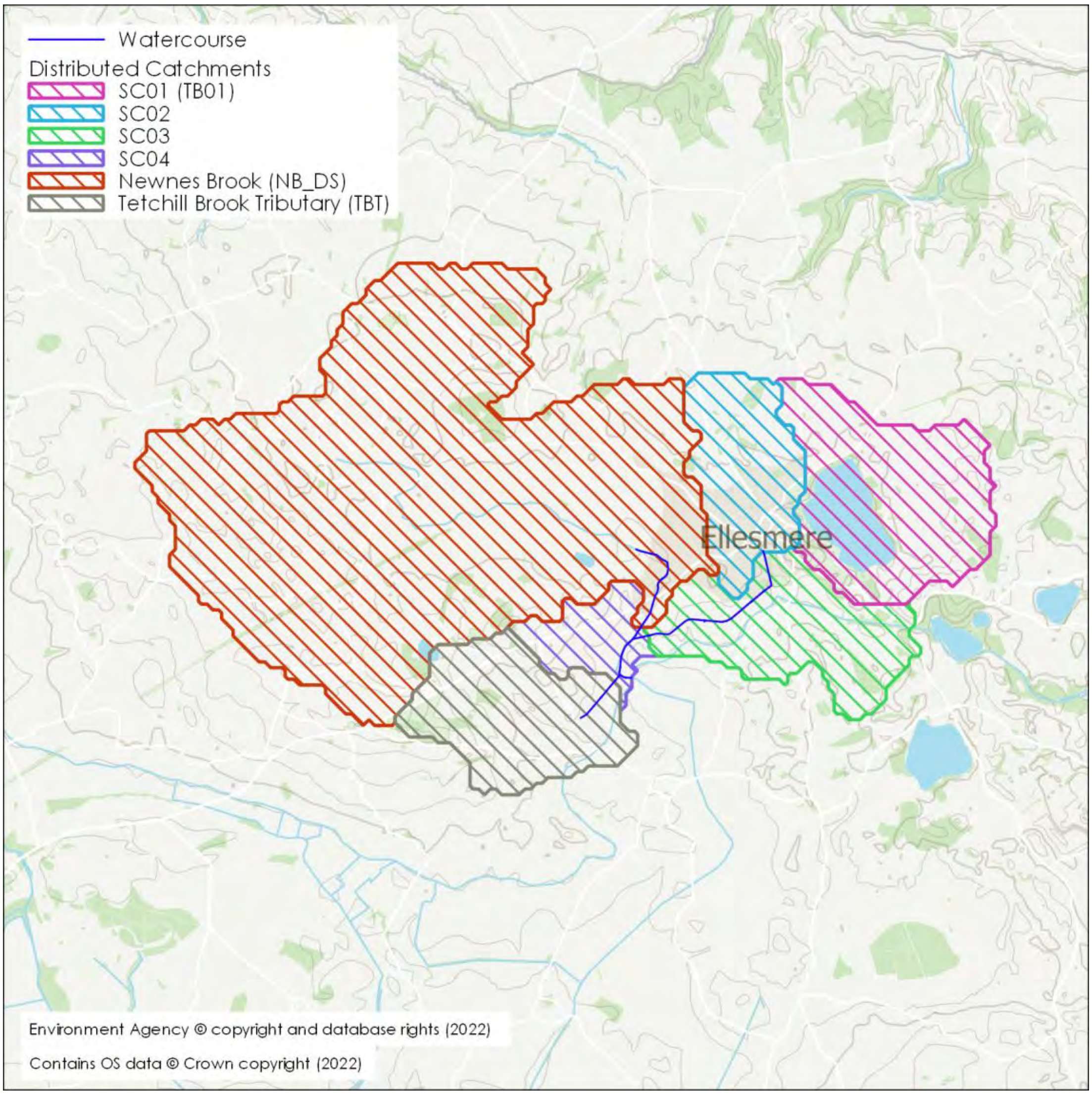

Figure 1.2: 2018 Model Inflow schematisation

2022 Assessment

1.10 This assessment is intended to update the 2014 / 2018 hydrological assessment using up to date methodologies, data, software and guidance.

1.11 Return periods assessed include: 5, 10, 20, 50, 75, 100, 200 and 1000-years. To inform the design event and potential future floodplain, the 1 in 100-year event with a range of climate change allowances applied will also be simulated in the hydraulic model. Hydrographs were required as well as peak flows.

1.12 This hydrological assessment was undertaken in March 2022. Version 5 of the Environment Agency (EA) Flood Estimation Guidelines[1] was referred to throughout the hydrological analysis.

[1] Technical Guidance 197_08 Flood Estimation Guidelines, Environment Agency (June 2020)

Available hydrometric data

1.13 There are no hydrometric gauges within the catchment. Therefore, there are no current hydrometric records of river flows or levels for the watercourse on which a hydrological assessment of flood flows can be made.

1.14 The National River Flow Archive (NRFA) Peak Flow Dataset Version 10 (released 27 August 2021) has been utilised in this assessment for the purposes of identifying any potential donor stations and for the development of pooling groups.

Initial choice of approach

Table 1.1: Method statement

Is FEH appropriate?	Yes. The study catchments are greater than 0.5km^2, are not considered to be highly permeable or heavily urbanised. FEH catchment descriptors show FARL to be low due to The Mere. However, The Mere is to be included within the hydraulic model; therefore, FARL will be updated to ensure the attenuation affect of The Mere is not double counted.
Initial choice of method(s) and reason	Both the FEH Statistical and the ReFH2 method have been used to estimate peak flows for lumped catchments. Both methods are suitable for the catchments and using both will enable comparison between the two flow estimation methods. A distributed approach using the 2018 subcatchment schematisation will be used. The lumped peak flow estimates will be applied to the subcatchments covering the upper reaches (SC01, Newnes Brook and Tetchill Brook Tributary). Catchment descriptors for the remaining subcatchments have been derived and input into ReFH2 to provide model inflows for the intervening 'lateral' areas. Futher information is provided in Section 6.
Software to be used	WINFAP v5 and ReFH2 version 3.2, WHS Permeable Adjustment Worksheet Beta v1.2

2. LOCATIONS WHERE FLOOD ESTIMATES ARE REQUIRED

Location of Flow Estimates

2.1 The National River Flow Archive (NRFA) Peak Flow Dataset Version 10 (released 27 August 2021) has been utilised in this assessment for the purposes of identifying any potential donor stations and for the development of pooling groups.

2.2 Flow estimation locations were chosen based on those used in the previous hydrological assessment to enable a comparison with the previous assessment and keep consistency with existing model inflow locations.

2.3 TB01, NB_DS and TBT provide lumped inflows for upstream extents of the modelled watercourses. TB02 and TB03 have been included as 'check flow' locations, to provide flows for undertaking sensibility check with model results. The catchment descriptors for TB02 and TB03 will also be utilised when estimating catchment descriptors for intervening 'lateral' catchments (see Section 6).

2.4 The flow estimation locations are shown in Figure 2.1Error! Reference source not found..

Table 2.1: Summary of subject sites

Site code	2018 Site Code	Watercourse	Site	Easting	Northing	Area on FEH Webservice	Revised area (if altered)
TB01	SC01	Tetchill Brook	Downstream of The Mere	340250	335000	2.5	-
TB02	-	Tetchill Brook	Downstream of Ellesmere at Dairy Grove	338950	334000	5.8	-
TB03	-	Tetchill Brook	Upstream of Tetchill Brook and Newnes Brook Confluence	338800	333550	19.7	-
NB_DS	Newnes Brook	Newnes Brook	Just upstream of confluence with Tetchill Brook	338900	334050	11.4	-
TBT	Tetchill Brook Tributary	Tributary of Tetchill Brook	Just upstream of confluence with Tetchill Brook	338650	333550	1.8	-

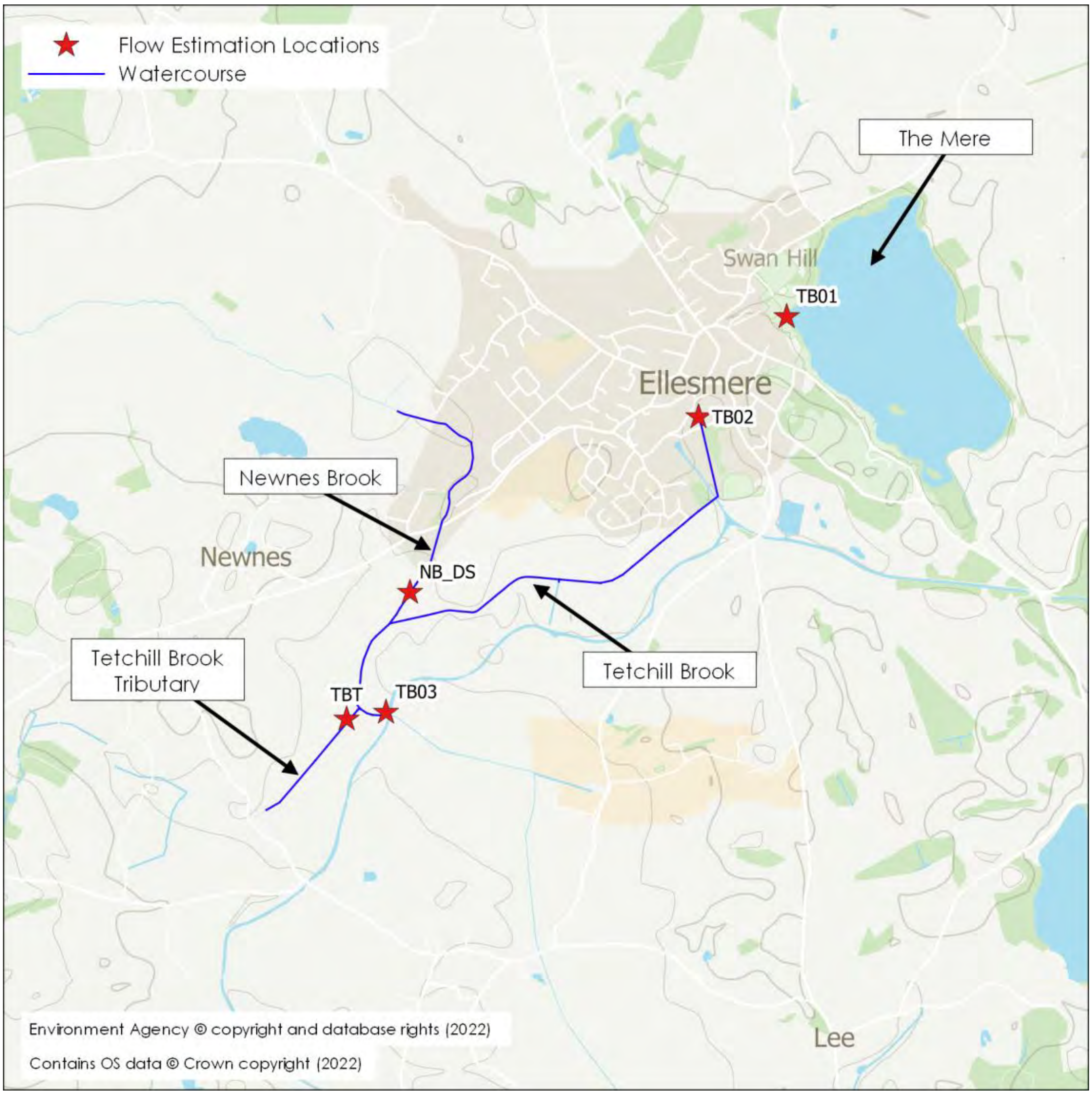

Figure 2.1: Flow Estimation Locations

Checking Catchment Descriptors

Table 2.2: Catchment Descriptor Checks

Record how catchment boundary was checked and describe any changes.	The catchment boundaries were initially identified using the FEH Web Service. The boundaries were reviewed using EA LiDAR. Following this review, the FEH catchment boundaries were retained. The catchment boundaries are shown in Figure 2.2Error! Reference source not found..
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	British Geological Survey (BGS) mapping indicates the overall catchment is underlain by a series of sandstone formations. This is predominantly overlain by Till Devensian – Diamicton superficial deposits, with pockets of Peat and Alluvium – Clay, Silt, Sand and Gravel. The main exception to this is the area of catchment downstream of the Tetchill Brook-Newnes Brook confluence with is underlain by Glaciofluvial Deposits – Devensian – Sand and Gravel.

	The underlying geology and soils suggest the BFIHOST and SPRHOST values of the FEH catchment descriptors are appropriate for the catchments. The Mere is included as part of the hydraulic model, with TB01 flows to be applied upstream of waterbody. Therefore, to avoid double-counting the attenuation affect of The Mere, FARL was set as 1 for TB01. TB02 and TB03 were adjusted, to discount The Mere but account for attenuation features downstream of The Mere, using the FEH procedure outlined in Volume 5 of the FEH Handbook.
Source of URBEXT	$URBEXT_{2000}$
Method for updating of URBEXT to present day.	CPRE formula from 2006 CEH report on $URBEXT_{2000}$

Table 2.3: Important catchment descriptors at each subject site (changes made are highlighted in red)

Site Code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR	SPRHOST	URBEXT 2000 *	FPEXT
TB01	1.000	0.34	0.637	1.88	23.2	708	34.15	0.0070	0.3262
TB02	0.985	0.36	0.701	3.17	21.3	710	29.62	0.0516	0.3094
TB03	0.995	0.43	0.542	4.24	25.3	726	34.87	0.0239	0.2266
NB_DS	0.988	0.51	0.417	4.45	23.4	734	39.05	0.0151	0.1989
TBT	0.993	0.51	0.701	1.28	45.7	734	26.92	0.0000	0.1168

* $URBEXT_{2000}$ updated to 2021

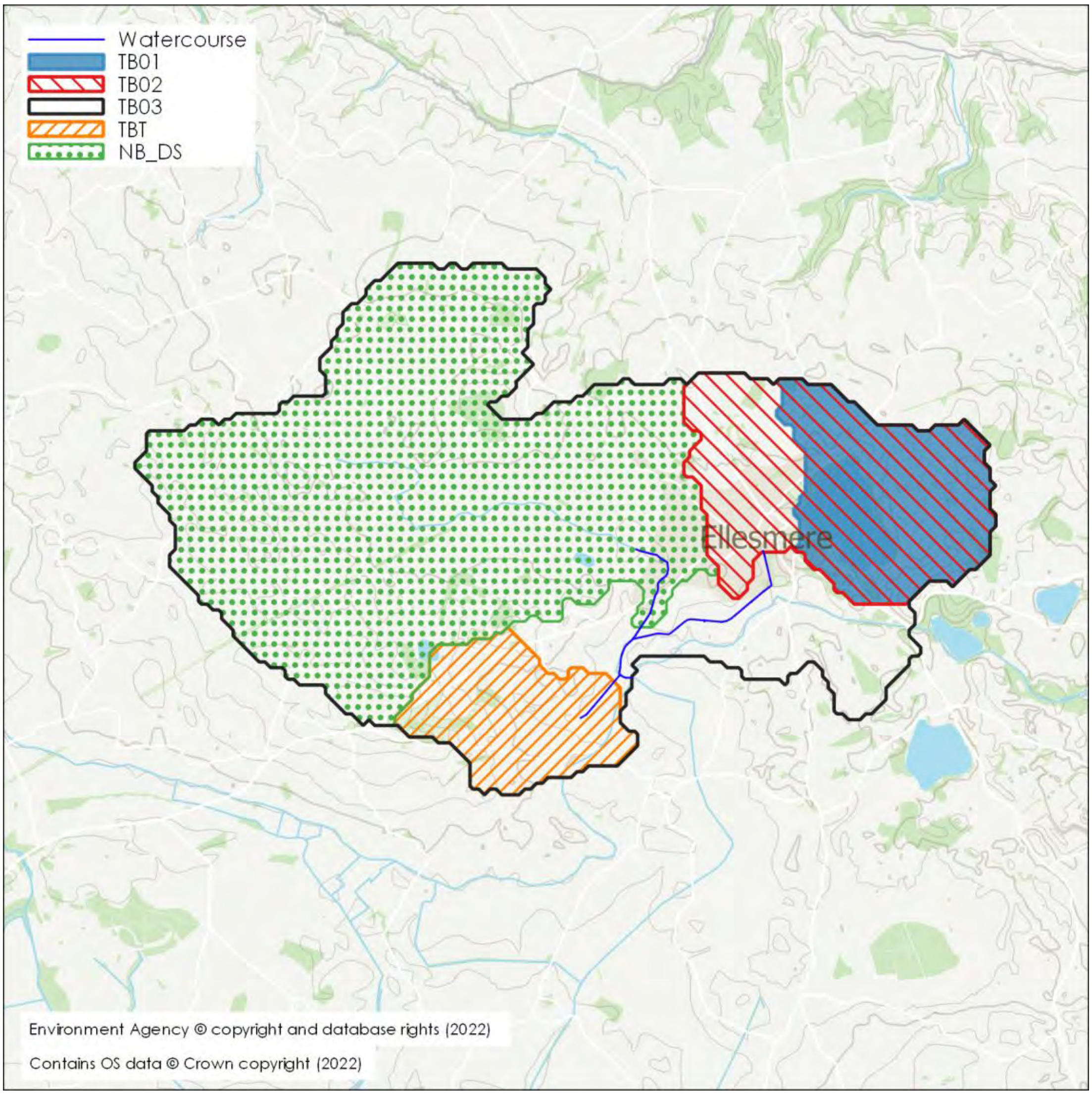

Figure 2.2: Catchment Boundaries

3. STATISTICAL METHOD

3.1 WINFAP was utilised to undertake a statistical analysis of the catchment using a hydrometric record of gauged catchments with similar characteristics.

QMED Development

3.2 Catchment descriptors were originally used to estimate the rural QMED of the study site using the revised equation from Science Report (SC050050). The FEH methodology states that flood frequency is best estimated by gauged data and estimation of key variables from catchment descriptors alone should be a method of last resort. As such, a search was undertaken to identify any potential donor sites that could be used to adjust QMED.

3.3 Phase 2 of Science Report SC090031[2] recommends using a single donor, chosen on the basis of proximity, to adjust QMED for 'small catchments' (defined as catchments with an area of less than 25km^2). This method can also be applied to catchments less than 40km^2.

3.4 With the guidance in mind, a search was undertaken within WINFAP to identify the closest station to the flow estimation points. The data quality of potential donors was also reviewed.

3.5 Details for the donor station used to adjust QMED, and which flow estimation point it has been applied to, are provided in Table 3.1. Details of the donor adjustments and final QMED estimation are provided in Table 3.2.

Table 3.1: Donor Station Details

Station Number	QMED from Observed Data (A)* (m^3/s)	QMED from Catchment Descriptors (B)** (m^3/s)	Adjustment Ratio (A/B)	Flow estimation point(s) donor is applied to
54020	10.37	15.348	0.68	All

* The default, deurbanised observed data was used
** The default, rural, QMED from catchment descriptors was used

3.6 Although the FEH only mentions performing the urban adjustment for urban catchments, the EA Flood Estimation Guidelines recommend applying it on all catchments to avoid a discontinuity when URBEXT2000 exceeds the threshold value of 0.030. As such, urban adjustment has been applied to all subject sites.

[2] Science Report SC090031/R0: Estimating flood peaks and hydrographs for small catchments (Phase 2), Environment Agency (2019).

Table 3.2: Overview of estimation of QMED at each subject site

Site Code	Method	Initial Estimate of QMED (M^3/s) (Rural)	Data Transfer				Final estimate of QMED (URBAN)
			Donor site NRFA no	Distance between centroids d_j (km)	Power term, a	Moderated QMED adjustment factor (A/B)[a]	
TB01	Donor transfer	0.37	54020	7.26	0.414	0.850	0.32
TB02		0.55		6.71	0.424	0.847	0.51
TB03		3.16		6.04	0.438	0.842	2.74
NB_DS		2.89		6.31	0.432	0.844	2.48
TBT		0.23		4.42	0.486	0.826	0.19

Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?	QMED values are consistent, increasing with distance downstream.
Which version of the urban adjustment was used for QMED?	Urban adjustment was applied using Kjeldsen (2010), as applied in WINFAP.

Derivation of Pooling Groups

3.7 A pooled group of hydrologically similar gauged sites was generated by the WINFAP software for the subject sites using the 'OK for Pooling' dataset. WINFAP uses the deurbanised pooling group L-moments as default.

3.8 Similarly to QMED estimations, the 'small catchment' method was adopted within WINFAP, in which the pooling group is selected using a similarity measure that only considered AREA and SAAR, as recommended by SC090031.

3.9 Two pooling groups were developed – one for the Tetchill Brook and its tributary and another for the Newnes Brook.

3.10 The pooling groups were reviewed to identify sites which may be inappropriate due to being significantly hydrologically dissimilar to the study site, or if they have any inaccuracies, uncertainties, or limitations in their data record.

3.11 The growth curve derived from the pooling group was also adjusted to reflect the urban influence using the methods adopted in WINFAP[3] which is based on those published by Kjeldsen (2010)[4].

3.12 Further detail on pooling group composition is provided in Section 8.

[3] Wallingford HydroSolutions (2016), WINFAP 4 Urban adjustment procedures, Wallingford HydroSolutions Ltd 2016.
[4] Kjeldsen, T.K., 2010. Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrology Research, volume 41, issue 5, pp391-405

Table 3.3: Derivation of pooling groups

Name of group	Site code from whose descriptors the group was derived	Subject site treated as gauged? (enhanced single site analysis)	Change made to default pooling group with reasons, including any sites investigated but retaining in the group	Weighted average L-moments L-CV and L-skew (before urban and permeable adjustment)
PG_TB	TB03	No	Stations Removed: 7011 – short record 28058 – growth curve reaching a natural bound resulting in a negative skew 33032 – non-flood years account for over 15% of the record. Stations Added: 27010 – added to give over 500 years Comments: Pooling group is classed as heterogeneous and a review of the pooling group is desirable. Following review it is not considered possible to improve the group further.	L-CV: 0.274 L-Skew: 0.196
PG_NB	NB_DS	No	Stations Removed: 7011 – short record 28058 – growth curve reaching a natural bound resulting in a negative skew 44008 – non-flood years account for over 15% of the record. Stations Added: 26013 and 41022 – added to give over 500 years Comments: Pooling group is classed as heterogeneous and a review of the pooling group is desirable. Following review it is not considered possible to improve the group further.	L-CV: 0.272 L-Skew: 0.200

Table 3.4: Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS)	If P, ESS or J, name of pooling group)	Distribution used and reason for choice	Note any urban or permeable adjustment	Growth factor for 1% AEP event
TB01	Pooled	TB_PG	Generalised logistic, Generalised Extreme Value and Kappa 3 all provided an acceptable fit. Generalised logistic was used as this is what is implemented within the WHS Permeable Adjustment Worksheet Beta v1.	Urban adjustment using methods adopted in WINFAP which is based on those published by Kjeldsen 2010 Permeable adjustment using WHS Permeable Adjustment Worksheet Beta v1.1	3.09
TB02					3.07
TB03					3.08
NB_DS		NB_PG			3.09
TBT		TB_PG			3.09

Table 3.5: Flood estimates from the Statistical method

Site Code	Flood peak (m^3/s) for the following return periods									
	2	5	10	20	30	50	75	100	200	1000
TB01	0.32	0.46	0.56	0.67	0.74	0.84	0.92	0.98	1.15	1.65
TB02	0.51	0.73	0.89	1.07	1.18	1.34	1.47	1.58	1.85	2.67
TB03	2.74	3.93	4.31	5.76	6.36	7.19	7.91	8.46	9.92	14.22
NB_DS	2.48	3.55	4.34	5.20	5.76	6.51	6.51	7.67	9.00	12.94
TBT	0.19	0.28	0.34	0.40	0.45	0.50	0.50	0.59	0.69	0.99

4. REVITALISED FLOOD HYDROGRAPH (REFH2) METHOD

4.1 The ReFH2 Revitalised Flood Hydrograph Modelling Software (Version 2.3) was used to undertake an estimation of the peak flows for the subject sites.

Table 4.1: Overview of parameters for ReFH2 method

Site code	Method OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer	Tp (hours) Time to peak	C_{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
All	Parameters calculated using the updated catchment descriptors from Table 2.2				
Description of flood event analysis carried out			No flood event analysis was possible due to a lack of gauged data for the catchments.		

Table 4.2: ReFH2 Recommended storm durations

Site code	Season of design event	Storm duration	Selected interval
TB01	Winter	5.5 hrs	0.5 hrs
TB02	Winter	7.5 hrs	0.5 hrs
TB03	Winter	7.5 hrs	0.5 hrs
NB_DS	Winter	6.5 hrs	0.5 hrs
TBT	Winter	2.25 hrs	0.25 hrs
Comments	The recommended storm duration for the Tetchill Brook is 7.5 hours at the crossing with the Llangollen Canal. The recommended storm duration for the Newnes Brook is similar at 6.5 hours. Therefore, the model will initially be run with a uniform 7.5 hour storm duration with a winter storm profile.		

Table 4.3: Flood estimates from the ReFH method (based on recommended duration for individual catchments)

Site Code	Flood peak (m^3/s) for the following return periods									
	2	5	10	20	30	50	75	100	200	1000
TB01	0.30	0.43	0.54	0.67	0.75	0.87	0.97	1.05	1.25	1.79
TB02	0.53	0.75	0.94	1.15	1.28	1.47	1.64	1.77	2.09	2.97
TB03	3.34	4.70	5.78	7.00	7.79	8.89	9.85	10.58	12.48	17.56
NB_DS	3.31	4.67	5.73	6.93	1.71	8.80	9.74	10.44	12.29	17.21

Site Code	Flood peak (m^3/s) for the following return periods									
	2	5	10	20	30	50	75	100	200	1000
TBT	0.24	0.37	0.48	0.61	0.70	0.82	0.93	1.01	1.23	1.84

5. DISCUSSION AND SUMMARY OF RESULTS

Comparison of method

5.1 A comparison of the peak flow results for the different estimation methods for the 1 in 2-year and 1 in 100-year events is provided in **Table 5.1**.

5.2 With the exception of the 1 in 2-year and 1 in 5-year events for TB01, ReFH2 provided the highest peak flows. **Error! Reference source not found.** shows the growth curves for TB03, NB_DS and TBT. The growth curves are largely consistent between Statistical and ReFH2 methods, with the exception of TBT which has a considerably steeper growth curve in comparison to the other sites. The 1 in 100-year growth factor for TBT is 4.27; this may be due to the higher permeability within this catchment. However, TB02 has a similar permeability (based on BFIHOST) and does not show the same steepness.

Table 5.1: Comparison of results

Site code	1 in 2-year peak flows			1 in 100-year peak flows		
	Statistical	ReFH	Ratio	Statistical	ReFH	Ratio
TB01	0.32	0.30	0.94	0.98	1.05	1.07
TB02	0.51	0.53	1.04	1.58	1.77	1.12
TB03	2.74	3.34	1.22	8.46	10.58	1.25
NB_DS	2.48	3.31	1.33	7.67	10.44	1.36
TBT	0.19	0.24	1.26	0.59	1.01	1.71

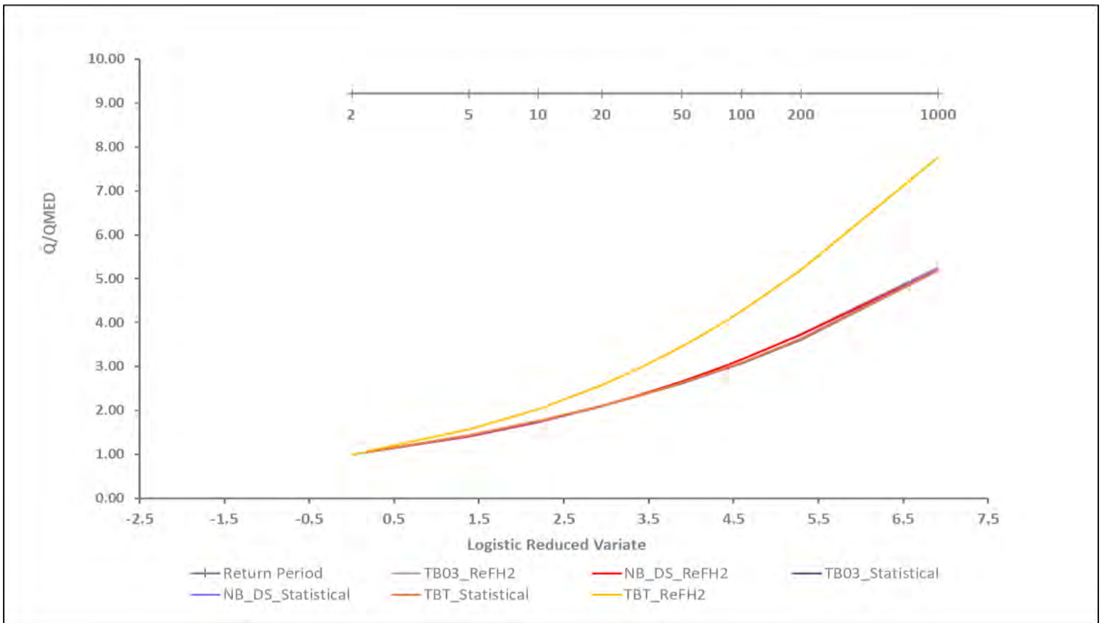

Figure 5.1: Comparison of Statistical method and ReFH growth curves

Final method and flows

Table 5.2: Final choice of method

Choice of method and justification	Either method is considered suitable for the catchments. However, the final choice of peak flows for input into the modelling study is the Statistical Method as it benefits from up-to-date flood peak data, using growth curves from hydrologically similar catchments to derive a growth curve. The Statistical Method also benefits from avoiding the need to make assumptions about factors such as rainfall duration, time of concentration and the nature of the design flood, unlike ReFH2. This is consistent with the FEH guidelines which states the Statististical method should often be preferred because it is based on a much larger dataset and has been more directly calibrated to reproduce flood frequency on UK catchments. The FEH also states final flows should not be chosen purely because they are more or less conservative. A distributed approach will be taken for inflows for the modelling. The Statistical peak flows for TB01, NM_DS and TBT will be used to provide inflows for the upstream extent of the Tetchill Brook and for the Newnes Brook and Tetchill Brook tributary inflows. The intervening 'lateral' area will accounted for using ReFH2 hydrographs. Further detail is provided in Section 6. TB02 and TB03 will be used to sensibility check the model results.

Table 5.3: Final Peak Flows from Chosen Method (Statistical)

Site Code	Flood peak (m^3/s) for the following return periods									
	2	5	10	20	30	50	75	100	200	1000
TB01	0.32	0.46	0.56	0.67	0.74	0.84	0.92	0.98	1.15	1.65
TB02	0.51	0.73	0.89	1.07	1.18	1.34	1.47	1.58	1.85	2.67
TB03	2.74	3.93	4.31	5.76	6.36	7.19	7.91	8.46	9.92	14.22
NB_DS	2.48	3.55	4.34	5.20	5.76	6.51	6.51	7.67	9.00	12.94
TBT	0.19	0.28	0.34	0.40	0.45	0.50	0.50	0.59	0.69	0.99

Table 5.4: Assumptions, limitations and uncertainty

List the main assumptions made	• The pooling groups are representative of the catchments. • The ReFH2 hydrograph shape is representative of the catchment response. • Tp and storm duration is representative of the catchment response. • Catchment descriptors derived for the lateral 'intervening' subcatchments are representative of the catchments.
Discuss any limitations e.g. applying methods outside the range of catchment types or return periods for which they were developed	• The FEH Statistical and ReFH2 methods are believed to be suitable up to the 1 in 200-year event. Estimates of flow beyond these events are extrapolations and, therefore, have a higher level of uncertainty. • There are only a small number of gauged sites in the UK. As such the representation in the pooling is not ideal given the small size of some of the study catchments. • There is no observed flow data within the catchment with which to verify the flow estimates.
Give what information you can on uncertainty in the results	According to Table 4 of the EA FEH Guidelines, confidence intervals for the 1 in 100 year for a rural site when calculated from catchment descriptors are quoted as 0.45-2.23 (for the 95% confidence interval). For a moderately urbanised site, the confidence intervals are 0.33-3.01. Confidence is considered to be improved when using observed data from a donor site. When one donor is used in the assessment, the confidence interval changes to 0.47-2.12 (for the 95% confidence interval) for a rural site and 0.34-2.94 for a moderately urbanised site. It is more difficult to quantify uncertainty in design flows estimated from the ReFH rainfall-runoff model. However, evidence[5] suggests the factorial standard errors from ReFH2 are comparable to those observed for the FEH pooled Statistical method when the catchment is treated as ungauged.
Comment on the suitability of the results for future studies	The design flow estimates have been derived for the purpose of providing flow hydrographs into a hydraulic model of the Tetchill Brook. Users for different studies should, as a minimum, review results to assess suitability for the purpose of the study.
Give any other comments on the study	While the installation of temporary flow gauges would provide local data with which to better inform the design peak flows, this would not align with the timescales of this project.

[5] Wallingford Hydrosolutions (2019) ReFH2 Science Report: Evaluation of the Rural Design Event Model.

Table 5.5: Checks

Are the results consistent?	Peak flows increase with distance downstream and are consistent with the size and characteristics of the catchments.
What do the results imply regarding the return periods of floods during the period of record?	It is not possible to imply return periods of floods due to the lack of gauged data within the study catchment and information on any historical flooding events.
What is the 1 in 100-year growth factor? (the guidance suggests a typical range or 2.1 to 4.0)	• Statistical Method: 3.07 – 3.09 • ReFH2 Method: 3.16 – 4.27 These fall within the typical range with the the ReFH growth factor for TBT. The higher growth factor for this location may be due to the higher permeability of the catchment.
If 1 in 1000-year flows have been derived, what is the range of ratios for 1 in 1000-year flow over 1 in 100-year flow?	• Statistical Method: 1.67 – 1.69 • ReFH2 Method: 1.66 – 1.82
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred	See Section 6.
Are the results consistent with the longer-term flood history?	It is not possible to compare the results with the longer-term flood history due to the lack of gauged data within the study catchment.
Describe any other checks on the results	Sensibility checks of modelled outlines will be undertaken at the modelling stage.

6. APPLICATION OF FLOWS TO MODEL

6.1 Flows are applied to the model using the same distributed approach as 2018, in which the catchment has been divided into a series of subcatchments. Figure 6.1 demonstrates how the flows will be applied to the model. Error! Reference source not found.

SC01, Newnes Brook and Tetchill Brook Tributary

6.2 ReFH2 hydrographs have been scaled to the Statistical peak flows calculated for TB01, NB_DS and TBT subcatchments, (SC01, Newnes Brook and Tetchill Brook Tributary, respectively). These hydrographs will be applied to the model as point inflows.

SC02, SC03 and SC04

6.3 Flows for the intervening 'lateral' subcatchments (SC02, SC03 and SC04) will be derived using ReFH2.

6.4 Catchment descriptors for these intervening areas have been by area weighting, using upstream and downstream lumped catchments. A sensibility check was undertaken on the resulting catchment descriptors to ensure they were sensible for the catchments. The following catchment descriptors were calculated manually:

- DPLBAR – calculated using using the standard equation for DPLBAR, given in the FEH Volume 5.
- FARL – calculated using the FEH procedure outlined in Volume 5 of the FEH Handbook.
- URBEXT2000 – calculated using URBAN50k method
- BFIHOST19 – the area weighted BFIHOST values were compared to BGS bedrock and superficial deposits information to check the values were representative.

6.5 The key catchment descriptors derived for the subcatchments are provided in Table 6.1.

Table 6.1: Intervening catchments – key catchment descriptors

Catchemnt Descriptor	Subcatchment		
	SC02	SC03	SC04
AREA	1.43	1.85	0.64
BFIHOST19	0.599	0.701	0.701
FARL	1.000	0.953	1.000
PROPWET	0.40	0.36	0.47
DPLBAR	1.21	1.40	0.78

Catchemnt Descriptor	Subcatchment		
	SC02	SC03	SC04
DPSBAR	16.29	22.58	37.24
FPEXT	0.240	0.340	0.280
SAAR	708	714	703
SPRHOST	35.03	29.62	26.92
URBEXT2000	0.238	0.017	0.010

6.6 These catchment descriptors were used within ReFH2 to create hydrographs for the required return period and the hydrographs distributed along the relevant reaches of the hydraulic model.

6.7 The Statistical method was the final choice of method for the lumped estimates and provided lower peaks flows compared to ReFH2. As such, using ReFH2 for the SC02, SC03 and SC04 subcatchments could overestimate flow in these locations. Therefore, the ReFH2 hydrographs for these subcatchments were scaled based on the average ratio between the Statistical and ReFH2 peak flows for the lumped estimates (80%).

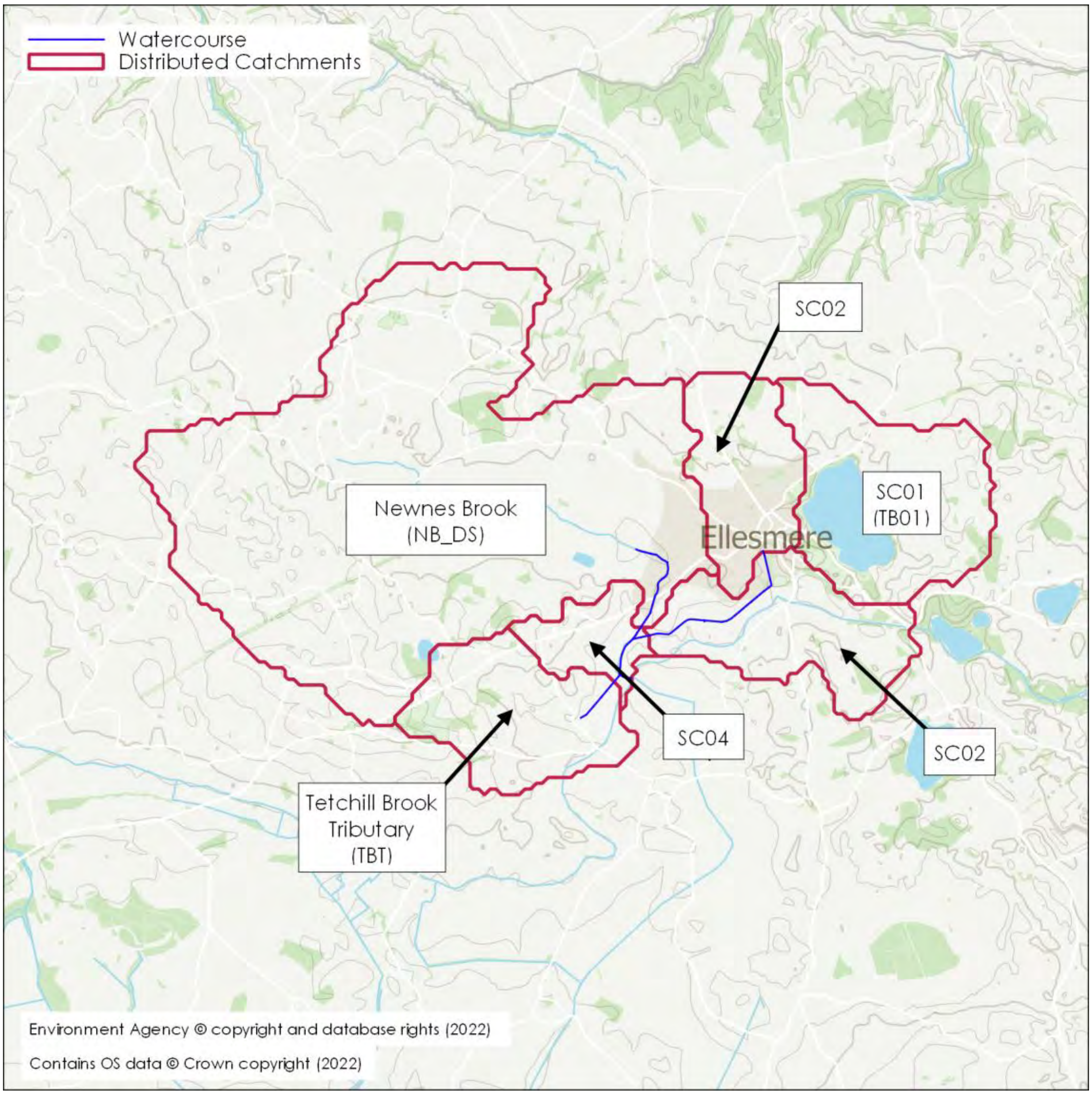

Figure 6.1: Application of inflows into model

7. COMPARISON WITH PREVIOUS ASSESSMENTS

7.1 The 2018 hydrological assessment included a Statistical estimate at the downstream extent of the Tetchill Brook (equivalent to location TB03 in this 2022 assessment). Table 7.1 provides a comparison of the calculated 1 in 100-year peak flows.

Table 7.1: Comparison of Peak Flow Estimates on Tetchill Brook

Assessment	Peak flow (m^3/s) Tetchill Brook at Llangollen Canal
2018	5.58
2022	8.46
% change	51.6%

7.2 The comparison shows the 2022 peak flow is higher than that calculated in 2018. The difference is due to changes in methodology, additional years of data in in the NRFA Peak Flow Dataset, and the new catchment descriptor BFIHOST19. Additionally, FARL has been updated in 2022 to avoid duplicating the attenuation effect of The Mere.

7.3 Table 7.2 provides a comparison between the 1 in 100-year peak flows used for each subcatchment for the 2018 and this 2022 assessment.

Table 7.2: Comparison of Final Model Inflows

Assessment	1 in 100-year Subcatchment Peak Flow (m^3/s)					
	SC01* (TB01)	SC02	SC03	SC04	Newnes Brook (NB_DS)	Tetchill Brook Tributary (TBT)
2018	0.20	1.39	0.31	0.48	10.0	1.51
2022	0.98	0.94	0.58	0.30	7.67	0.59
% change	-	-32%	87%	-37%	-23%	-61%

* note: SC01 was restricted in 2018 to 0.2m^3/s due to an outfall structure, therefore a direct comparison between results is not possible

7.4 The comparison shows the majority of the 2022 flows are less than those for the 2018 study. This is due to a different choice in method for Newnes Brook and Tetchill Brook Tributary – the 2018 assessment used ReFH2, the 2022 assessment used Statistical Method. Both 2028 and 2022 studies used ReFH2 flows for the intervening catchments (SC02, SC030 and SC03). However, the difference in peak flows can be explained by the new catchment descriptor, BFIHOST19, and the scaling of the hydrographs based on the average ratio between the Statistical and ReFH2 peak flows for the lumped estimates.

7.5 The 2022 peak flow estimates should be preferred to those used in 2018. The 2022 estimates are based on up to date guidance, methodologies, data and software.

8. SUPPORTING INFORMATION

Flood history

8.1 A flood history review for the area has been undertaken using Environment Agency recorded flood outlines, the Shropshire Level 1 Strategic Flood Risk Assessment[6], Shropshire County Council Flood Investigation Reports, the British Chronology of Hydrological Events and online newspaper reports.

8.2 No record of flooding with the study catchments has been found during this search.

Detailed pooling group information

8.3 The default pooling group generated by WINFAP is provided in Table 8.1 and Table 8.4 and the final pooling group following review is provided in Table 8.2 and Table 8.5. Permeable adjusted L-CV and L-Skew are provided in Table 8.3 and Table 8.6.

Table 8.1: Default pooling group: TB_PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
26016 (Gypsey Race @ Kirby Grindalythe)	0.209	23	0.101	0.312	0.258	0.187
26014 (Water Forlornes @ Driffield)	0.395	22	0.431	0.299	0.119	0.501
25019 (Leven @ Easby)	0.438	42	5.384	0.339	0.385	0.766
7011 (Black Burn @ Pluscarden Abbey)	0.574	7	5.205	0.544	0.571	2.928
39033 (Winterbourne Stream @ Bagnor)	0.66	58	0.401	0.342	0.382	1.613
36010 (Bumpstead Brook @ Broad Green)	0.66	53	7.5	0.379	0.172	1.353
24007 (Browney @ Lanchester)	0.701	15	10.981	0.222	0.211	1.242
27073 (Brompton Beck @ Snainton Ings)	0.707	40	0.816	0.215	0.019	0.393
33054 (Babingley @ Castle Rising)	0.732	44	1.132	0.205	0.068	0.595
41020 (Bevern Stream @ Clappers Bridge)	0.737	51	13.66	0.205	0.171	1.255
53017 (Boyd @ Bitton)	0.761	47	13.87	0.245	0.08	0.161
9006 (Deskford Burn @ Cullen)	0.778	9	21.783	0.3	0.129	0.471
28058 (Henmore Brook @ Ashbourne)	0.801	13	8.838	0.19	-0.111	1.411
26013 (Driffield Trout Stream @ Driffield)	0.802	10	2.685	0.293	0.28	2.582
27051 (Crimple @ Burn Bridge)	0.839	48	4.544	0.22	0.145	0.357
33032 (Heacham @ Heacham)	0.843	52	0.442	0.299	0.138	0.186
Total		5.34				
Weighted Means				0.286	0.182	
H2 value	3.666					
Goodness of Fit	Generalised Logistic			General Extreme Value		
	1.7224			-0.4252		

[6] Shropshire Council, Shropshire Level 1 Strategic Flood Risk Assessment, October 2018

Table 8.2: Final pooling group (before permeable adjustment): TB+PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
26016 (Gypsey Race @ Kirby Grindalythe)	0.209	23	0.101	0.312	0.258	0.27
26014 (Water Forlornes @ Driffield)	0.395	22	0.431	0.299	0.119	0.611
25019 (Leven @ Easby)	0.438	42	5.384	0.339	0.385	1.074
39033 (Winterbourne Stream @ Bagnor)	0.66	58	0.401	0.342	0.382	1.658
36010 (Bumpstead Brook @ Broad Green)	0.66	53	7.5	0.379	0.172	1.938
24007 (Browney @ Lanchester)	0.701	15	10.981	0.222	0.211	0.922
27073 (Brompton Beck @ Snainton Ings)	0.707	40	0.816	0.215	0.019	0.881
33054 (Babingley @ Castle Rising)	0.732	44	1.132	0.205	0.068	0.915
41020 (Bevern Stream @ Clappers Bridge)	0.737	51	13.66	0.205	0.171	0.942
53017 (Boyd @ Bitton)	0.761	47	13.87	0.245	0.08	0.37
9006 (Deskford Burn @ Cullen)	0.778	9	21.783	0.3	0.129	0.579
26013 (Driffield Trout Stream @ Driffield)	0.802	10	2.685	0.293	0.28	2.456
27051 (Crimple @ Burn Bridge)	0.839	48	4.544	0.22	0.145	0.299
27010 (Hodge Beck @ Bransdale Weir)	0.881	41	9.42	0.224	0.293	1.086
Total		503				
Weighted Means				0.274	0.196	
H2 value	3.1141					
Goodness of Fit	Generalised Logistic			General Extreme Value		
	1.199			-0.751		

Table 8.3: Permeable adjusted L-CV and L-Skew: TB_PG

Station	Adjusted L-CV	Adjusted L-Skew
26016 (Gypsey Race @ Kirby Grindalythe)	0.283	0.313
26014 (Water Forlornes @ Driffield)	0.287	0.099
27073 (Brompton Beck @ Snainton Ings)	0.199	0.055
33054 (Babingley @ Castle Rising)	0.190	0.113

Table 8.4: Default pooling group: NB_PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
26016 (Gypsey Race @ Kirby Grindalythe)	0.273	23	0.101	0.312	0.258	0.11
27073 (Brompton Beck @ Snainton Ings)	0.282	40	0.816	0.215	0.019	0.481
25019 (Leven @ Easby)	0.415	42	5.384	0.339	0.385	0.514
27051 (Crimple @ Burn Bridge)	0.512	48	4.544	0.22	0.145	0.269
26014 (Water Forlornes @ Driffield)	0.826	22	0.431	0.299	0.119	0.476
27010 (Hodge Beck @ Bransdale Weir)	0.936	41	9.42	0.224	0.293	1.159
36010 (Bumpstead Brook @ Broad Green)	0.943	53	7.5	0.379	0.172	1.315
7011 (Black Burn @ Pluscarden Abbey)	0.956	7	5.205	0.544	0.571	2.391
44008 (South Winterbourne @ Winterbourne Steepleton)	1.024	41	0.448	0.408	0.318	0.636
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.045	10	5.972	0.257	0.135	2.255
41020 (Bevern Stream @ Clappers Bridge)	1.045	51	13.66	0.205	0.171	0.804
39033 (Winterbourne Stream @ Bagnor)	1.091	58	0.401	0.342	0.382	1.132
24007 (Browney @ Lanchester)	1.103	15	10.981	0.222	0.211	1.204
28058 (Henmore Brook @ Ashbourne)	1.116	13	8.838	0.19	-0.111	1.671
33054 (Babingley @ Castle Rising)	1.16	44	1.132	0.205	0.068	0.584
Total		508				
Weighted Means				0.286	0.204	
H2 value	4.1461					
Goodness of Fit	Generalised Logistic			General Extreme Value		
	1.0484			-0.7092		

Table 8.5: Final pooling group (before permeable adjustment): NB_PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
26016 (Gypsey Race @ Kirby Grindalythe)	0.273	23	0.101	0.312	0.258	0.273
27073 (Brompton Beck @ Snainton Ings)	0.282	40	0.816	0.215	0.02	1.082
25019 (Leven @ Easby)	0.415	42	5.384	0.339	0.386	1.077
27051 (Crimple @ Burn Bridge)	0.512	48	4.544	0.22	0.146	0.289
26014 (Water Forlornes @ Driffield)	0.826	22	0.431	0.299	0.12	0.611
27010 (Hodge Beck @ Bransdale Weir)	0.936	41	9.42	0.224	0.293	1.116
36010 (Bumpstead Brook @ Broad Green)	0.943	53	7.5	0.379	0.173	2.124
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.045	10	5.972	0.257	0.136	1.221
41020 (Bevern Stream @ Clappers Bridge)	1.045	51	13.66	0.205	0.174	0.969
39033 (Winterbourne Stream @ Bagnor)	1.091	58	0.401	0.342	0.383	1.507
24007 (Browney @ Lanchester)	1.103	15	10.981	0.222	0.212	0.685

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
33054 (Babingley @ Castle Rising)	1.16	44	1.132	0.205	0.069	1.078
26013 (Driffield Trout Stream @ Driffield)	1.231	10	2.685	0.293	0.281	1.73
41022 (Lod @ Halfway Bridge)	1.284	50	16.25	0.297	0.174	0.237
Total		507				
Weighted Means				0.272	0.200	
H2 value	3.0761					
Goodness of Fit	Generalised Logistic			General Extreme Value		
	1.5836			-0.2250		

Table 8.6: Permeable adjusted L-CV and L-Skew: NB_PG

Station	Adjusted L-CV	Adjusted L-Skew
26016 (Gypsey Race @ Kirby Grindalythe)	0.283	0.313
27073 (Brompton Beck @ Snainton Ings)	0.199	0.055
26014 (Water Forlornes @ Driffield)	0.287	0.099
33054 (Babingley @ Castle Rising)	0.190	0.113

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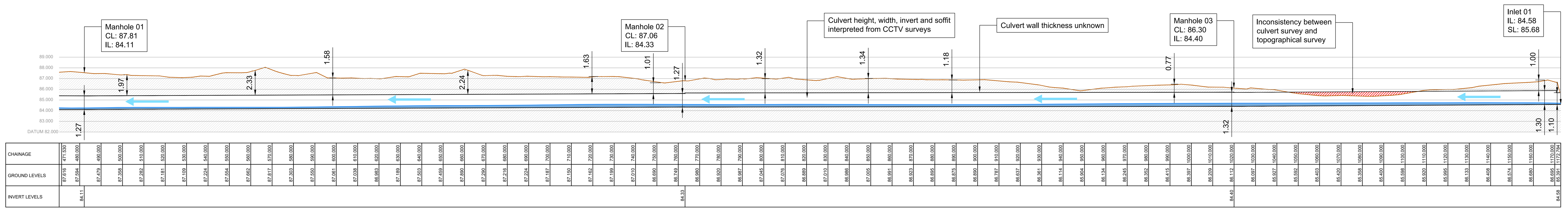
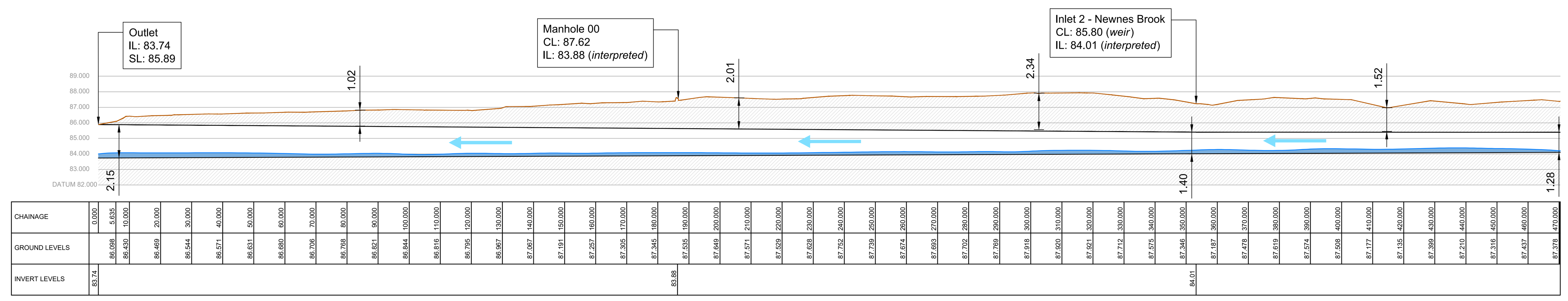
Appendix 2: Summary of CCTV Surveys

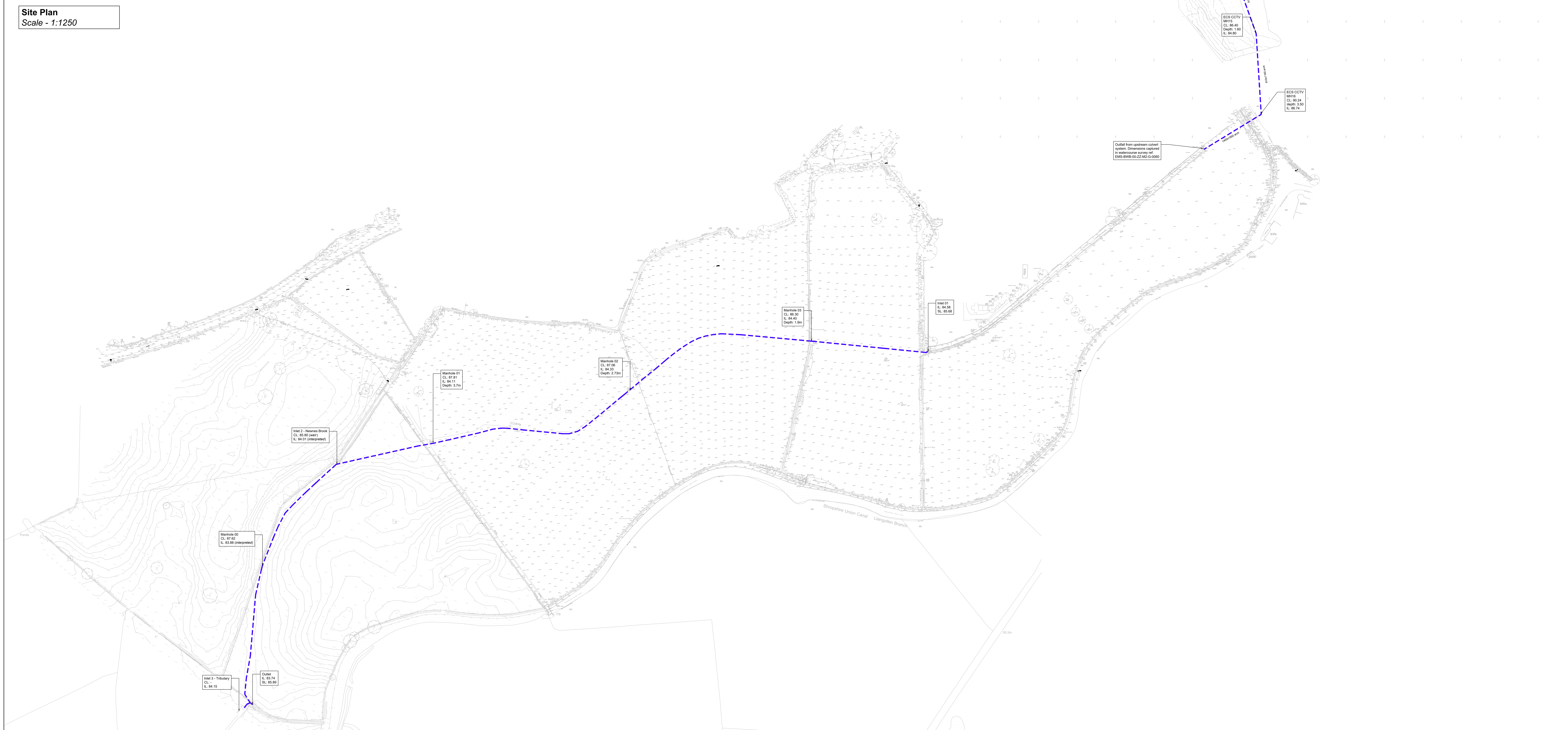
Tetchill Brook Culvert - Downstream Reach
Scale - 1:1000



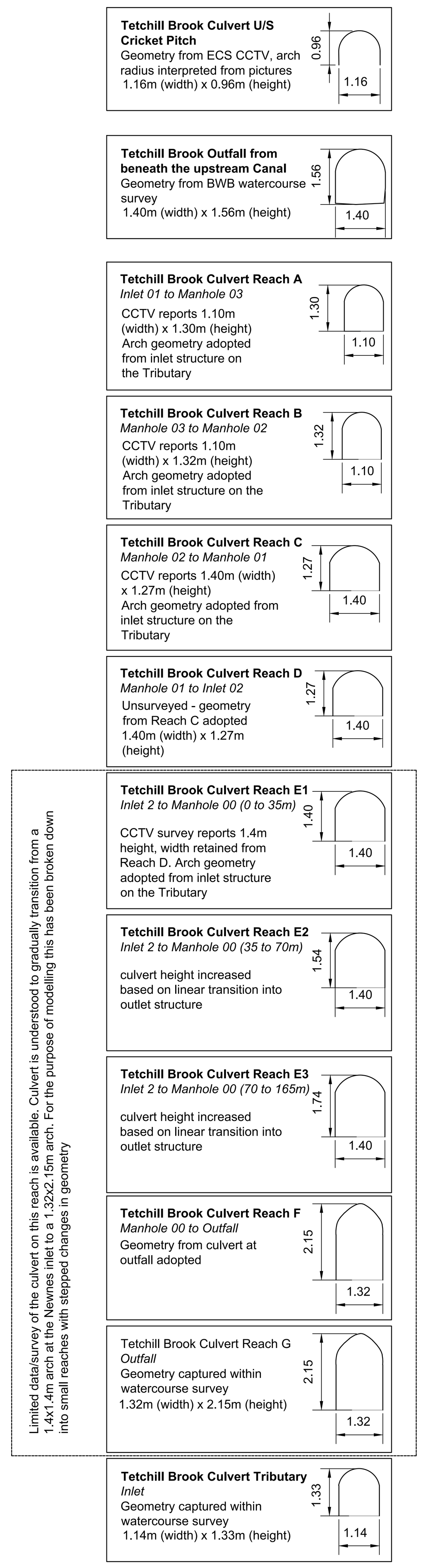
Tetchill Brook Culvert - Downstream Reach
Scale - 1:1000



Site Plan
Scale - 1:1250



Interpreted Culvert Geometry
Scale - 1:100



Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.
5. Culvert geometry interpreted from available CCTV and topographical surveys. Detailed dimensional survey would be required to confirm geometry.

Legend

– – Tetchill Brook Culvert

ISSUES & REVISIONS

Rev	Date	Details of issue / revision	Drw	Rev
P1	21.12.17	PRELIMINARY ISSUE	RG	SN
P2	09.02.18	General Update	RG	SN
P3	22.02.18	General Update	RG	SN
P4	30.03.22	General Update	RG	SN

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Drawn:	R Green	Reviewed:	S Nelmes
BWB Ref:	BMW 2025	Date:	21.12.17
Scale@A0:	As Shown		

Project Title: **Ellesmere**

Drawing Status: **PRELIMINARY**

Drawing Title: **Tetchill Brook Culvert Review**

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMM-BWB-EWE-XX-DR-YE-0001	S2	P4

Appendix 3: Watercourse Surveys

NOTES

1. DO NOT SCALE THIS DRAWING. ALL DIMENSIONS MUST BE CHECKED/ VERIFIED ON SITE. IF IN DOUBT ASK.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS AND SPECIALISTS DRAWINGS AND SPECIFICATIONS.
3. ALL DIMENSIONS IN METRES UNLESS NOTED OTHERWISE. ALL LEVELS IN METRES UNLESS NOTED OTHERWISE.
4. ANY DISCREPANCIES NOTED ON SITE ARE TO BE REPORTED TO THE ENGINEER IMMEDIATELY.
5. NO SCALE FACTOR HAS BEEN APPLIED TO THIS SURVEY, THEREFORE THE OS COORDINATES ARE TO BE TREATED AS ARBITRARY. PLEASE REFER TO SURVEY STATION INFORMATION BELOW FOR ON SITE CONTROL ESTABLISHMENT.
6. ALL COORDINATES AND HEIGHT DATA RELATE TO OSGB36 UNLESS OTHERWISE STATED. CONTROL STATIONS ARE COORDINATED BY MEANS OF GPS RECEIVING REALTIME CORRECTIONS VIA OS SMART NET.
7. ALL MANHOLE DATA IS COLLECTED FROM GROUND LEVEL THEREFORE DISCREPANCIES MAY OCCUR. MORE ACCURATE DATA IS ONLY ACHIEVABLE VIA CONFINED SPACE ENTRY.

LEGEND

	Buildings / Walls	Elec	Electric
	Kerb/Cannel line	CTV	Cable TV
	Edge of surface	BT	British Telecom
	Canopy / Overhang	FH	Fire Hydrant
	Line Marking	ST	Stop tap
	Fence/Barrier	SV	Stop valve
	Gate	WM	Water Meter
	Hedge	Mkr	Service Marker
	Overhead Powerline	RE	Rodding eye
1	Station and Name	AV	Air Valve
	Tree / Bush / Sapling	CMP	Cable Marker Post
	Area of Undergrowth / Extent of Tree Canopy	LP	Lamp Post
	Body of Water	SP	Sign Post
	OS Buildings	EP	Electricity Post
	Surveyed Buildings	TP	Telegraph Post
MH	Manhole	TL	Traffic light
IC	Inspection chamber	BS	Bus Stop
CL	Cover level	FL	Floodlight
IL	Invert level	FP	Flagpole
P.Inv Ø0.25	Pipe invert (diameter)	PB	Post box
GY	Gully	LB	Litter Bin
Bg	Back Gully	BO	Bollard
UTL	Unable to Lift	TCB	Telephone call box
0.25	Flow direction and pipe diameter	WL	Water level
		ht	Height
		FFL	Finished floor level
		THL	Threshold level
		DK	Drop kerb
		GV	Gas Valve
		ER	Earth rod

Rev	Date	Details of issue / revision	Drw	Rev
C1	07/08/13	Drawing Issue	SDS	TDP

ISSUES & REVISIONS

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Client
BURBURY INVESTMENTS LTD

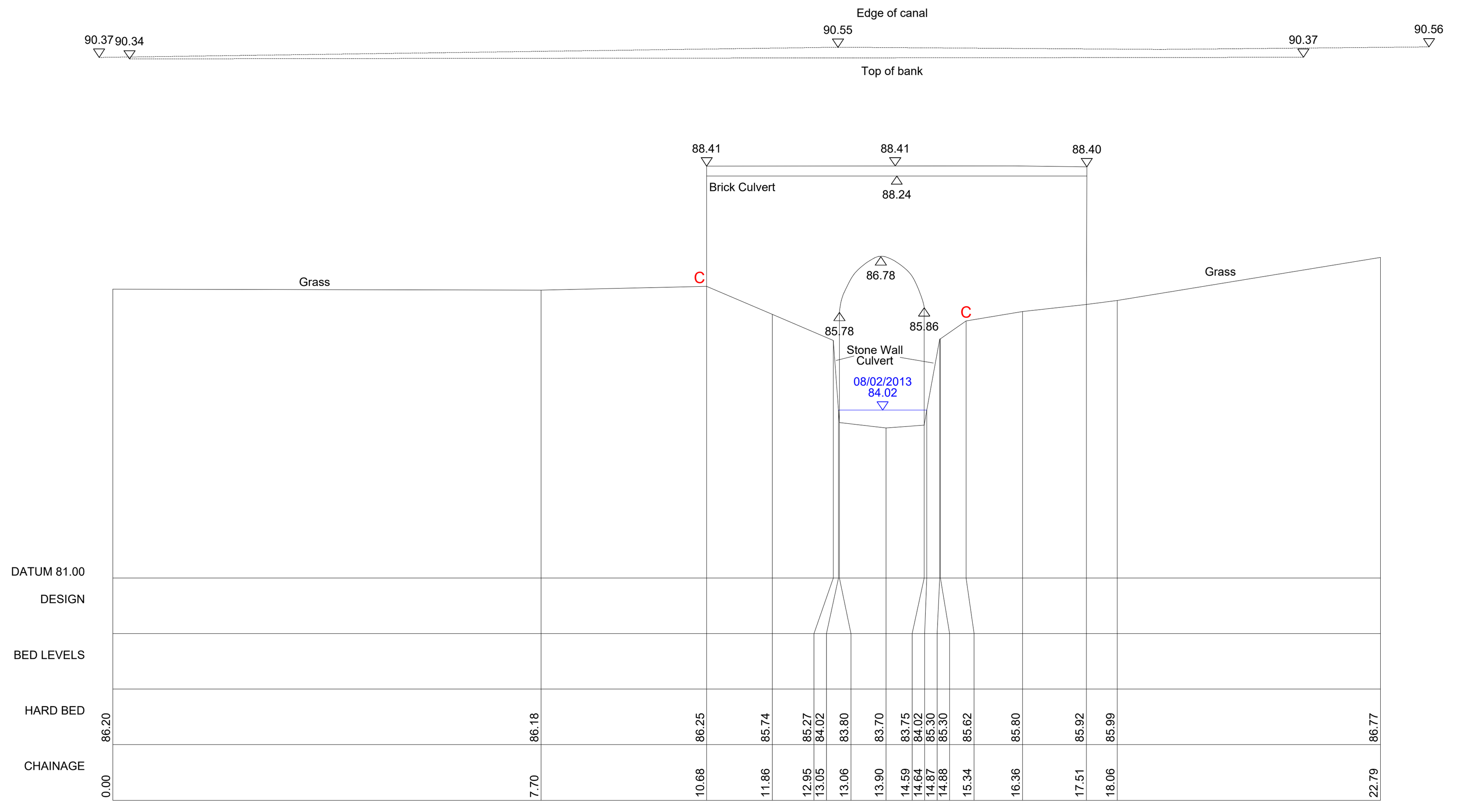
Project Title
NEWNES BROOK ELLESMERE MARINA

Drawing Title
SECTION LOCATION PLAN

Scale	1:1000 @ A1	Drawn	SDS
Size	A1	Reviewed	TDP

Drawing Status
CONSTRUCTION

Drawing No.	Revision
BMW/2025/SVY/101	C1



001
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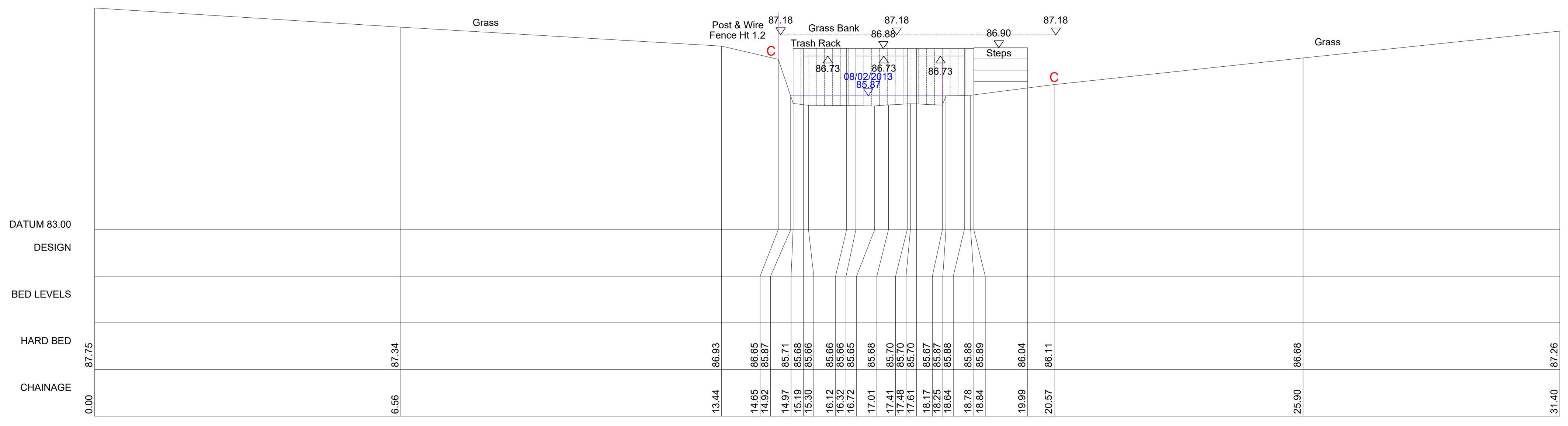
Chainage 29.5
Upstream Face of Canal Culvert



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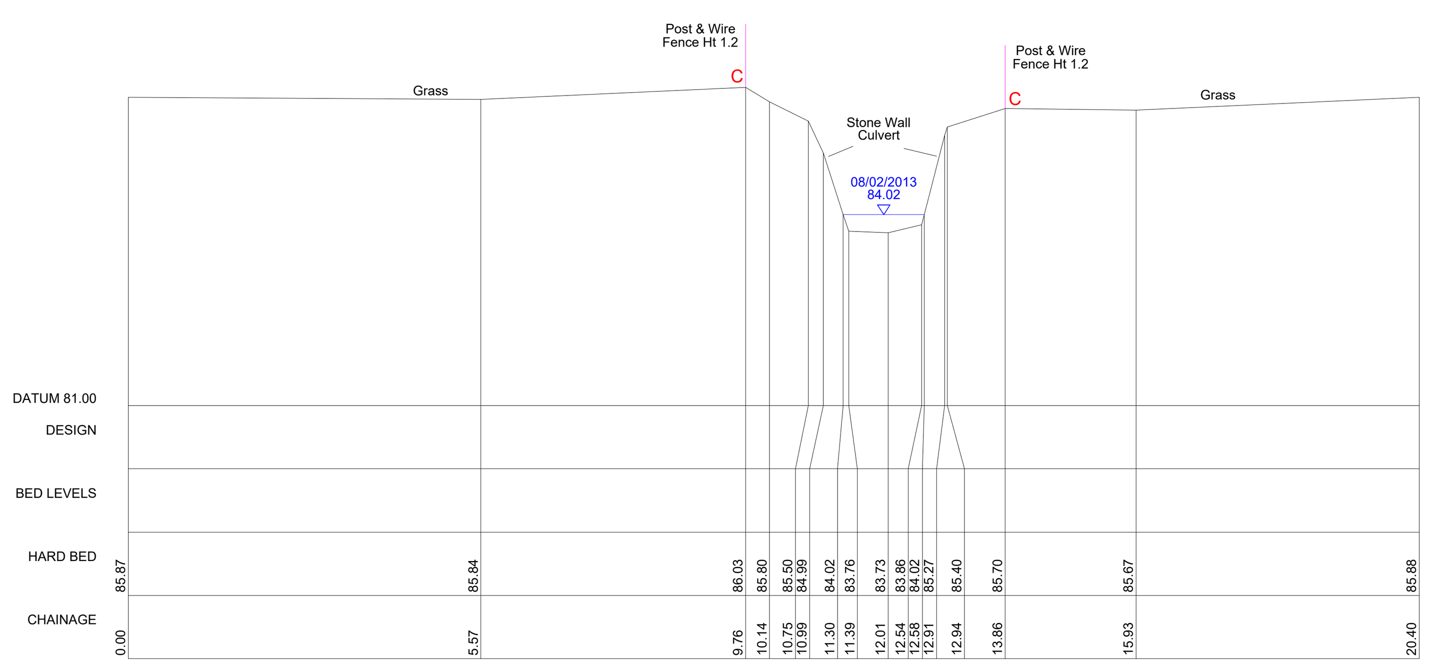
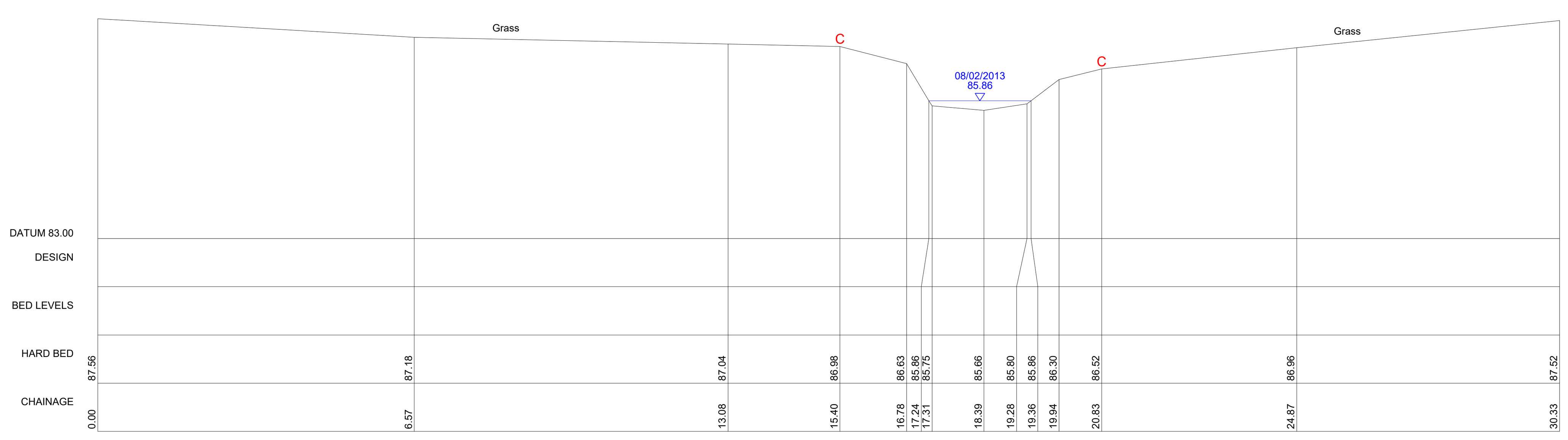
Chainage 463.4
Upstream Face Culvert



002
338772.59mE 333601.4mN Brg 184
Chainage 74.0
Open Channel



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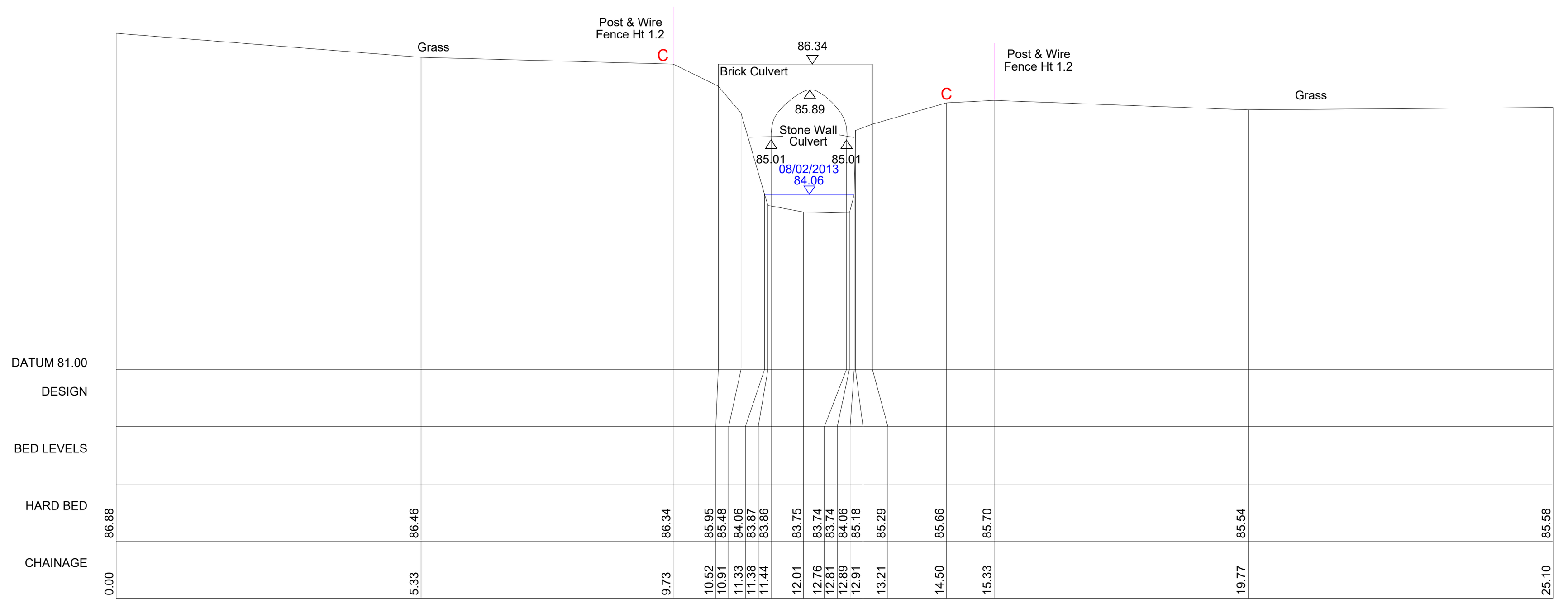
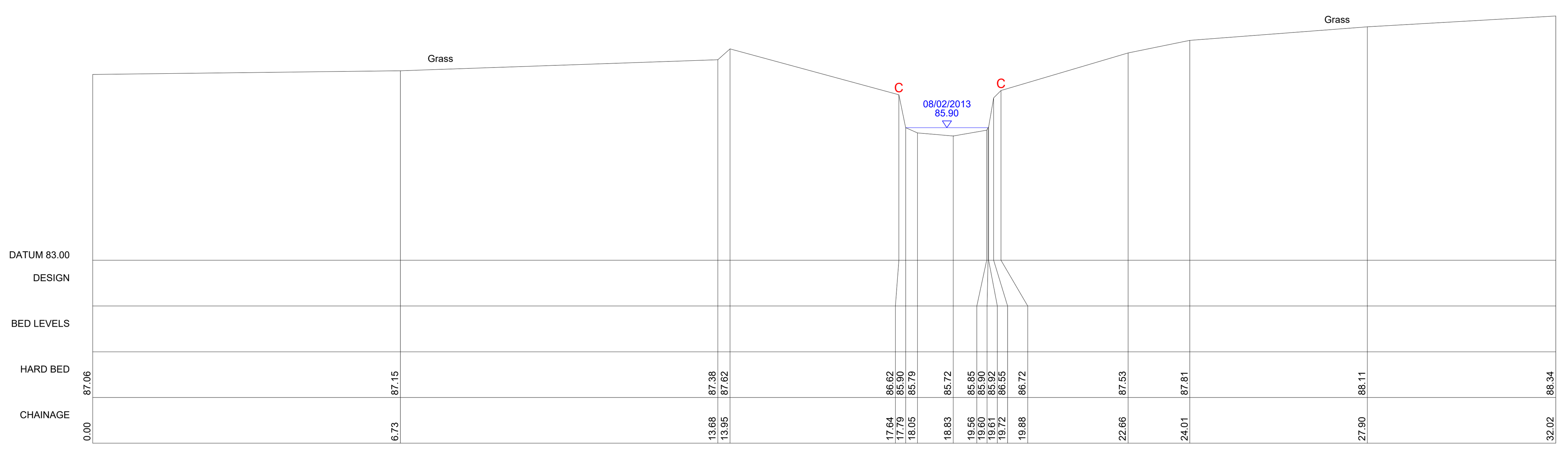
Chainage 474.2
Open Channel



003
338734.92mE 333621.01mN Brg 215
Chainage 124.0
Downstream Face Culvert



006
338885.26mE 333965.91mN Brg 316
Chainage 525.5
Open Channel

NOTES

1. DO NOT SCALE THIS DRAWING. ALL DIMENSIONS MUST BE CHECKED/ VERIFIED ON SITE. IF IN DOUBT ASK.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS AND SPECIALISTS DRAWINGS AND SPECIFICATIONS.
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LEGEND

	Buildings / Walls	Elec	Electric
	Kerb/Cannel line	CTV	Cable TV
	Edge of surface	BT	British Telecom
	Canopy / Overhang	FH	Fire Hydrant
	Line Marking	ST	Stop tap
	Fence/Barrier	SV	Stop valve
	Gate	WM	Water Meter
	Hedge	Mkr	Service Marker
	Overhead Powerline	RE	Rodding eye
1	Station and Name	AV	Air Valve
	Tree / Bush / Sapling	CMP	Cable Marker Post
	Area of Undergrowth / Extent of Tree Canopy	LP	Lamp Post
	Body of Water	SP	Sign Post
	OS Buildings	EP	Electricity Post
	Surveyed Buildings	TP	Telegraph Post
		TL	Traffic light
		BS	Bus Stop
		FL	Floodlight
		FP	Flagpole
		PB	Post box
		LB	Litter Bin
MH	Manhole	BO	Bollard
IC	Inspection chamber	TCB	Telephone call box
CL	Cover level	WL	Water level
IL	Invert level	ht	Height
P.Inv Ø0.25	Pipe invert (diameter)	FFL	Finished floor level
GY	Gully	THL	Threshold level
Bg	Back Gully	DK	Drop kerb
UTL	Unable to Lift	GV	Gas Valve
0.25	Flow direction and pipe diameter	ER	Earth rod

Rev	Date	Details of issue / revision	Drw	Rev
C1	07/08/13	Drawing Issue	SDS	TDP

ISSUES & REVISIONS

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Client
BURBURY INVESTMENTS LTD

Project Title
NEWNES BROOK ELLESMERE MARINA

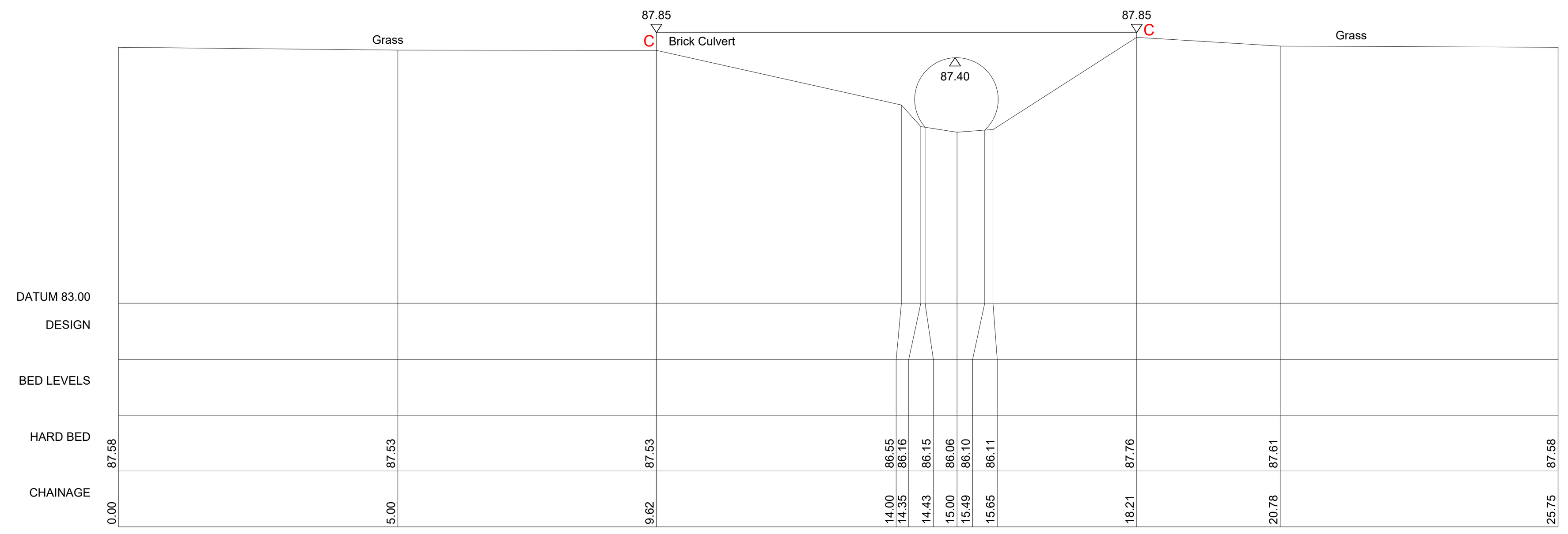
Drawing Title
CROSS SECTIONS 1-6

Scale	1:100 @ A1	Drawn	SDS
Size	A1	Reviewed	TDP

Drawing Status
CONSTRUCTION

Drawing No.
BMW/2025/SVY/102

Revision
C1



007
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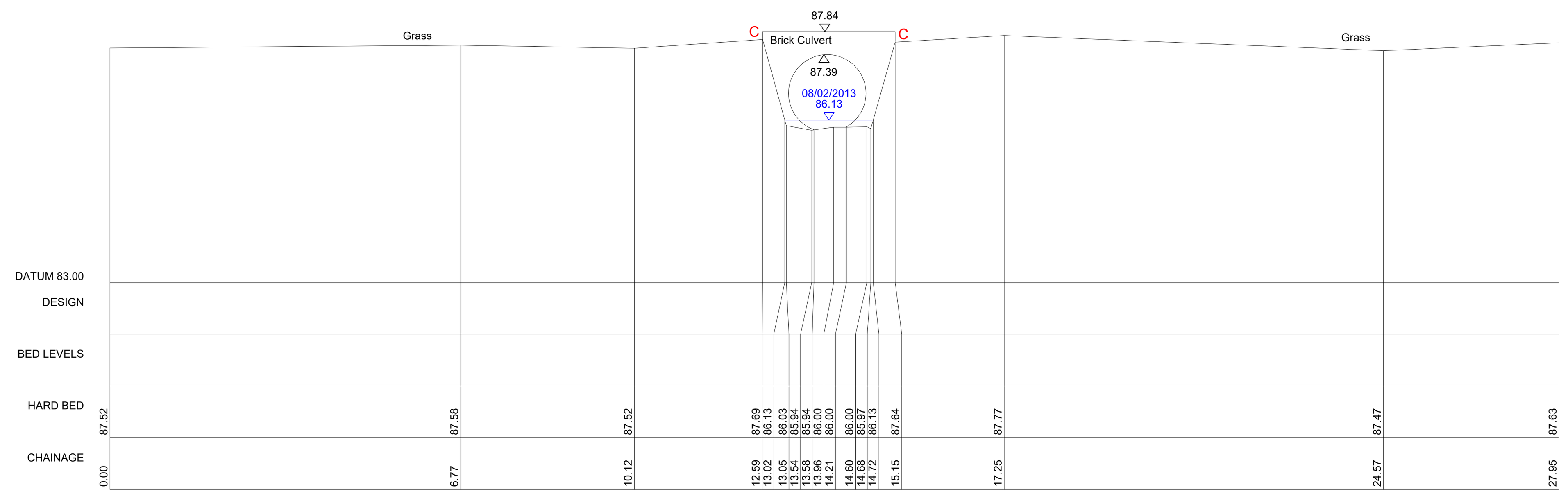
Chainage 581.0
Downstream Face Culvert



008
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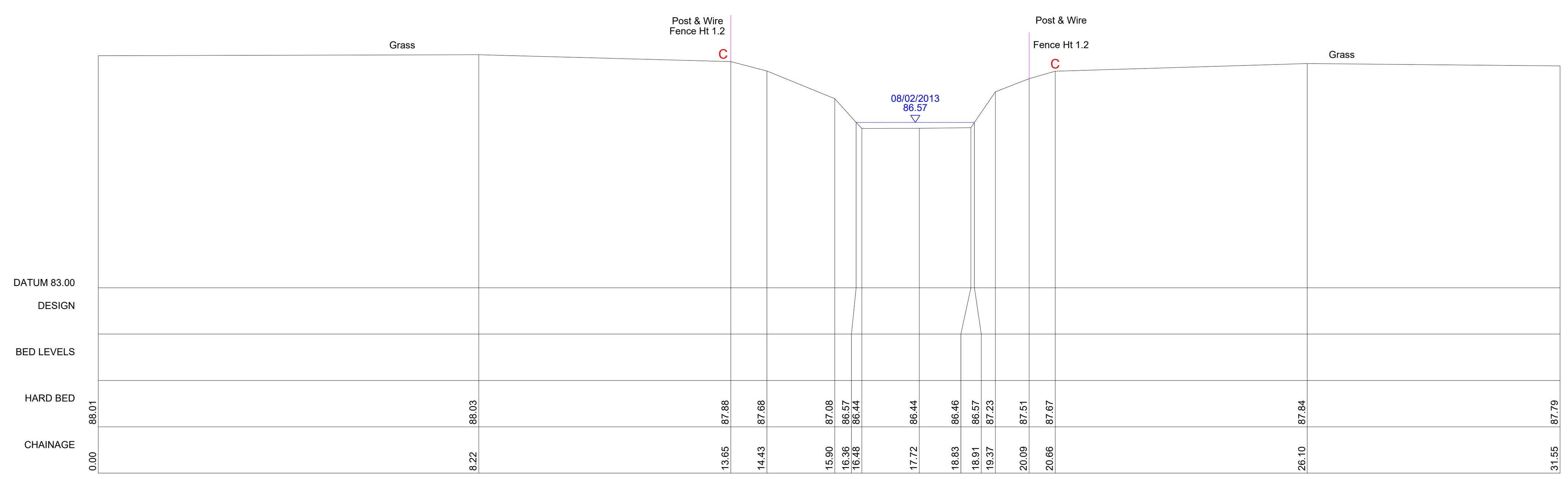
Chainage 591.1
Upstream Face Culvert



009
338962.06mE 334082.58mN Brg 304
Chainage 661.3
Open Channel

NOTES

1. DO NOT SCALE THIS DRAWING. ALL DIMENSIONS MUST BE CHECKED/ VERIFIED ON SITE. IF IN DOUBT ASK.
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LEGEND

Buildings / Walls; Kerb/Cannel line; Edge of surface; Canopy / Overhang; Line Marking; Fence/Barrier; Gate; Hedge; Overhead Powerline; Station and Name; Tree / Bush / Sapling; Area of Undergrowth / Extent of Tree Canopy; Body of Water; OS Buildings; Surveyed Buildings

MH	Manhole	Elec	Electric
IC	Inspection chamber	CTV	Cable TV
CL	Cover level	BT	British Telecom
IL	Invert level	FH	Fire Hydrant
P.Inv Ø0.25	Pipe invert (diameter)	ST	Stop tap
GY	Gully	SV	Stop valve
Bg	Back Gully	WM	Water Meter
UTL	Unable to Lift	Mkr	Service Marker
0.25	Flow direction and pipe diameter	RE	Rodding eye
		AV	Air Valve
		CMP	Cable Marker Post
		LP	Lamp Post
		SP	Sign Post
		EP	Electricity Post
		TP	Telegraph Post
		TL	Traffic light
		BS	Bus Stop
		FL	Floodlight
		FP	Flagpole
		PB	Post box
		LB	Litter Bin
		BO	Bollard
		TCB	Telephone call box
		WL	Water level
		ht	Height
		FFL	Finished floor level
		THL	Threshold level
		DK	Drop kerb
		GV	Gas Valve
		ER	Earth rod

Rev	Date	Details of issue / revision	Drw	Rev
C1	07/08/13	Drawing Issue	SDS	TDP

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Client
BURBURY INVESTMENTS LTD

Project Title
NEWNES BROOK ELLESMERE MARINA

Drawing Title
CROSS SECTIONS 7-9

Scale	1:100 @ A1	Drawn	SDS
Size	A1	Reviewed	TDP

Drawing Status
CONSTRUCTION

Drawing No.	Revision
BMW/2025/SVY/103	C1

Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in metres unless noted otherwise. All levels in metres unless noted otherwise.
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6. All coordinates and height data relate to OSGB36(15). Control stations are coordinated by means of GPS receiving real time corrections via OS smart net.
7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Legend

- OS Buildings
- Surveyed Buildings
- Building
- Wall
- Kerb Channel Line
- Top of Kerb
- Edge of Surface
- Top of Bank
- Bottom of Bank
- Canopy / Overhang
- Line Marking
- Centre Line
- Watercourse Centre Line
- Barrier
- Fence
- Gate
- Overhead Powerline
- Overhead Utilities
- Contour Lines (120)
- Inspection Chamber
- Flow direction and pipe diameter (0.25)
- Station and Name (1)
- Monitoring Borehole (BH 1)
- Tree / Bush / Sapling
- Area of Vegetation/ Extent of Tree Canopy
- Hedge
- Body of Water
- Body of Water from OS
- Spot Level (+50.00)
- Assumed Surface Water Drainage Line
- Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	15.09.17	First Issue	LP	DS

Issues & Revisions

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Client

BURBURY INVESTMENTS LTD.

Project Title

ELLESMERE MARINE

Drawing Title

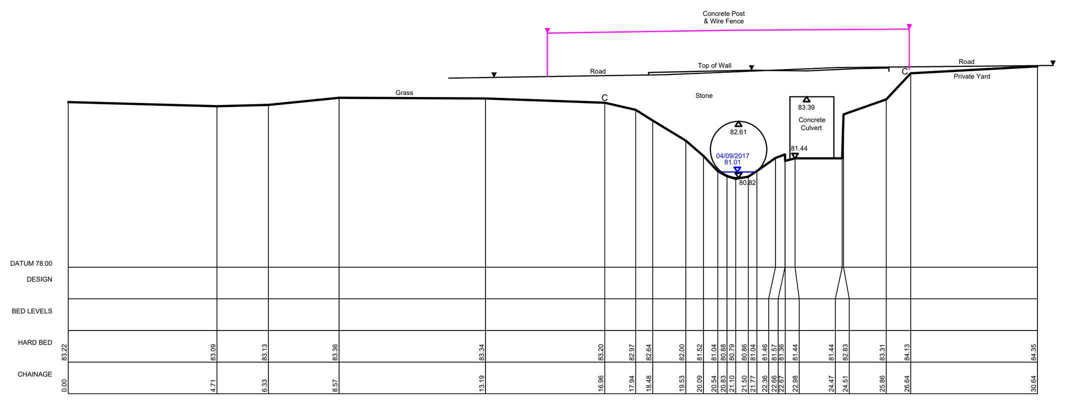
WATERCOURSE SURVEY SHEET 1 OF 4

Drawn:	L.Padmore		Reviewed:	D.Smith	
BWB Ref:	BMW 2025	Date:	15.09.17	Scale@A1:	1:500

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMM-BWB-00-01-DR-G-001	S2	P1



TBR1.001
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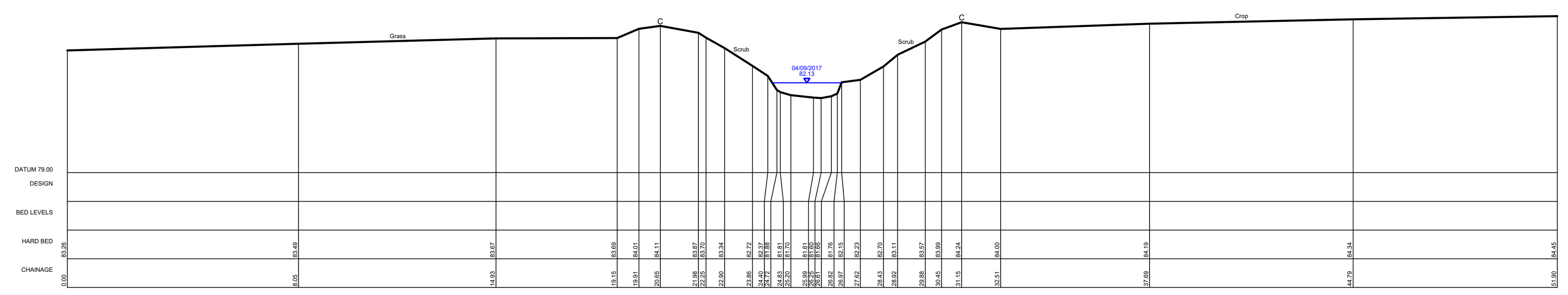
Chainage 0.4m
Culvert



TBR1.003
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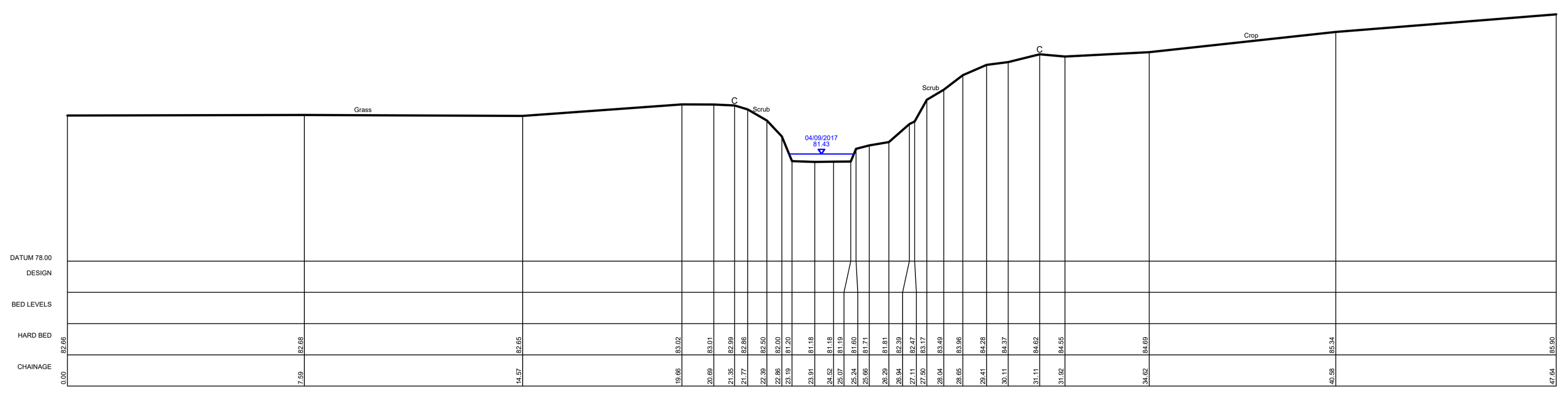
Chainage 445.6m
Open Channel



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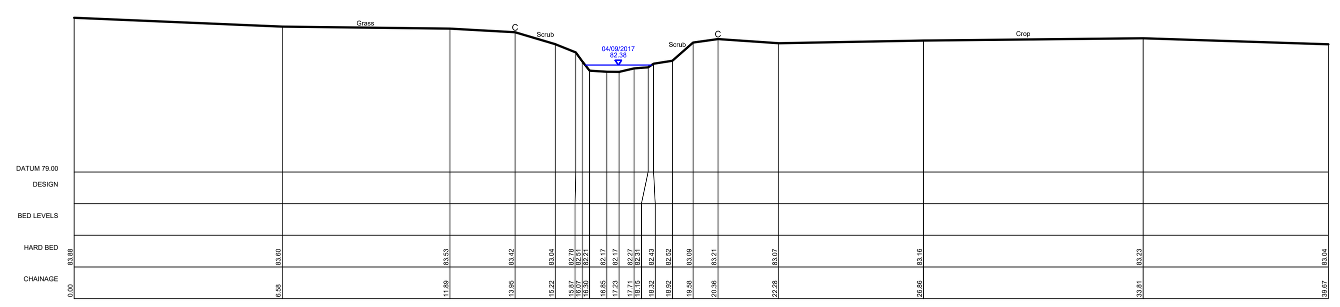
Chainage 108.2m
Open Channel



TBR1.004
339363.81mE 333396.79mN Brg 210
Chainage 673.2m
Open Channel

Notes

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7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
0.25 Flow direction and pipe diameter
1 Station and Name
BH 1 Monitoring Borehole
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
+50.00 Spot Level
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	15.09.17	First Issue	LP	DS

Issues & Revisions

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Client
BURBURY INVESTMENTS LTD.

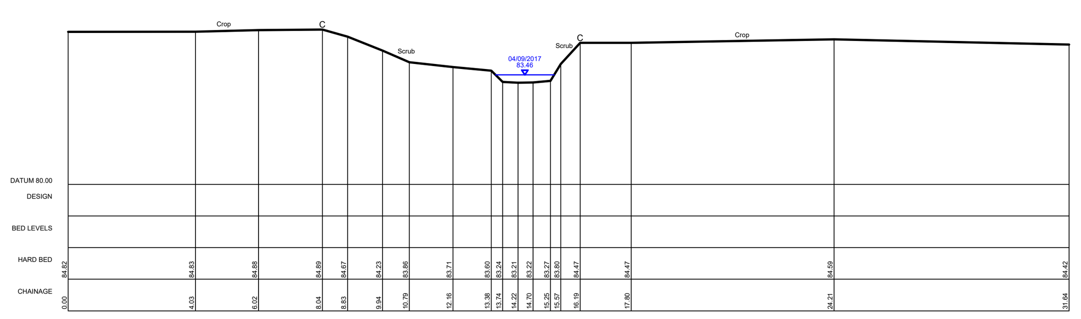
Project Title
ELLESMERE MARINE

Drawing Title
WATERCOURSE SURVEY SHEET 2 OF 4

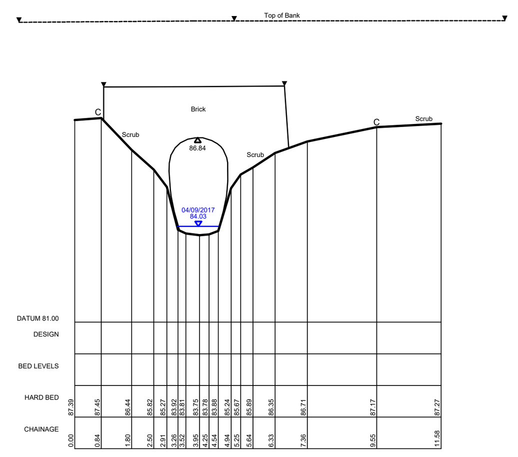
Drawn:	L.Padmore	Reviewed:	D.Smith
BWB Ref:	BMW 2025	Date: 15.09.17	Scale@A1: 1:200

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMM-BWB-00-02-DR-G-001	S2	P1



TBR1.005
339026.35mE 333471.5mN Brg 196
Chainage 1014.3m
Open Channel



TBR1.007
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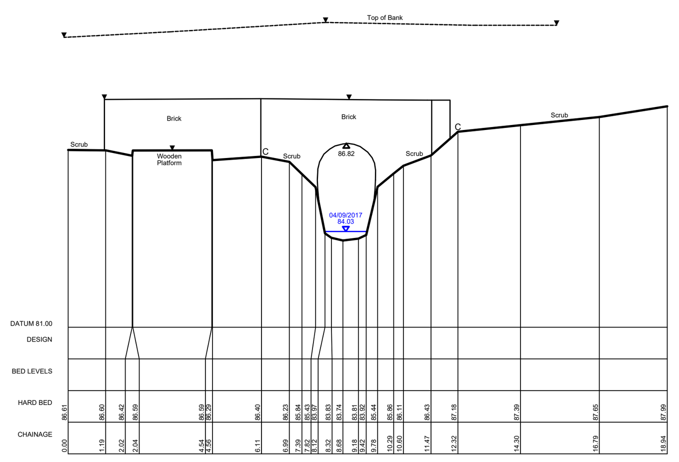
Chainage 1259.4m
Culvert



TBR1.006
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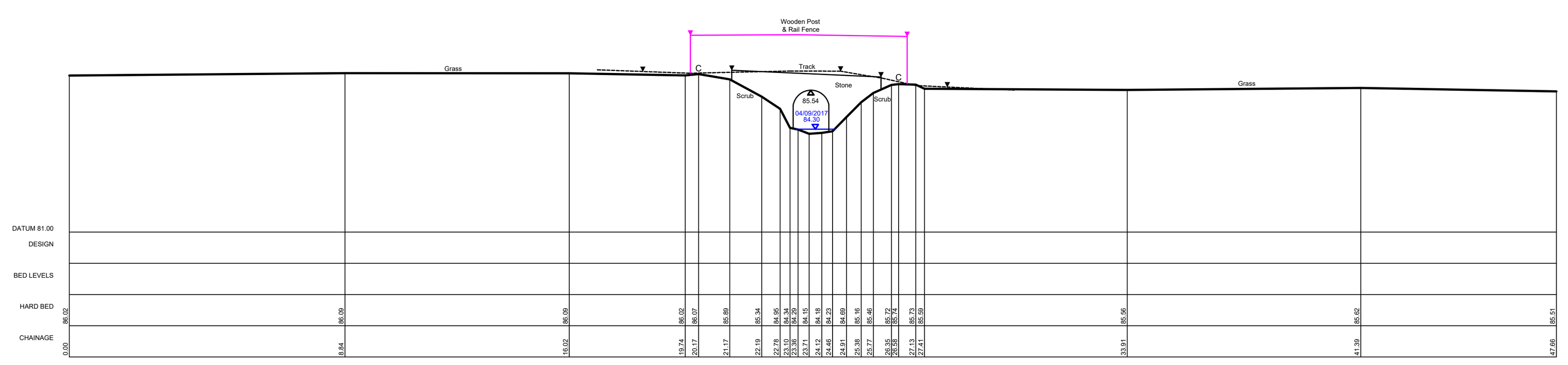
Chainage 1231.6m
Culvert



TBR1.008
338699.24mE 333623.32mN Brg 133
Chainage 1370.6m
Culvert

Notes

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8. OS license number: 100022432

Legend

- OS Buildings
- Surveyed Buildings
- Building
- Wall
- Kerb Channel Line
- Top of Kerb
- Edge of Surface
- Top of Bank
- Bottom of Bank
- Canopy / Overhang
- Line Marking
- Centre Line
- Watercourse Centre Line
- Barrier
- Fence
- Gate
- Overhead Powerline
- Overhead Utilities
- Contour Lines
- Inspection Chamber
- 0.25 — Flow direction and pipe diameter
- 1 — Station and Name
- BH 1 — Monitoring Borehole
- Tree / Bush / Sapling
- Area of Vegetation/ Extent of Tree Canopy
- Hedge
- Body of Water
- Body of Water from OS
- +50.00 — Spot Level
- Assumed Surface Water Drainage Line
- Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	15.09.17	First Issue	LP	DS

Issues & Revisions

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Client

BURBURY INVESTMENTS LTD.

Project Title

ELLESMERE MARINE

Drawing Title

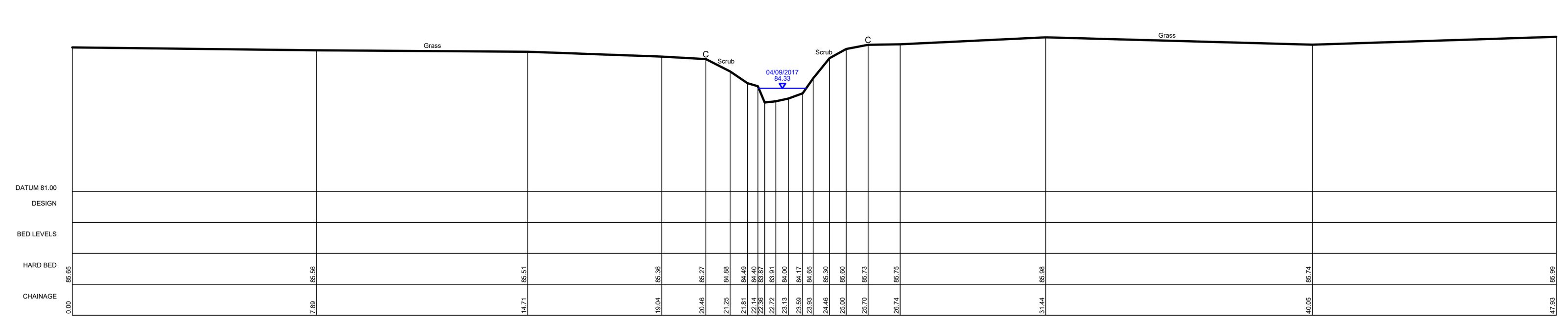
WATERCOURSE SURVEY SHEET 3 OF 4

Drawn:	L.Padmore	Reviewed:	D.Smith
BWB Ref:	BMW 2025 Date:	15.09.17 Scale@A1:	1:200

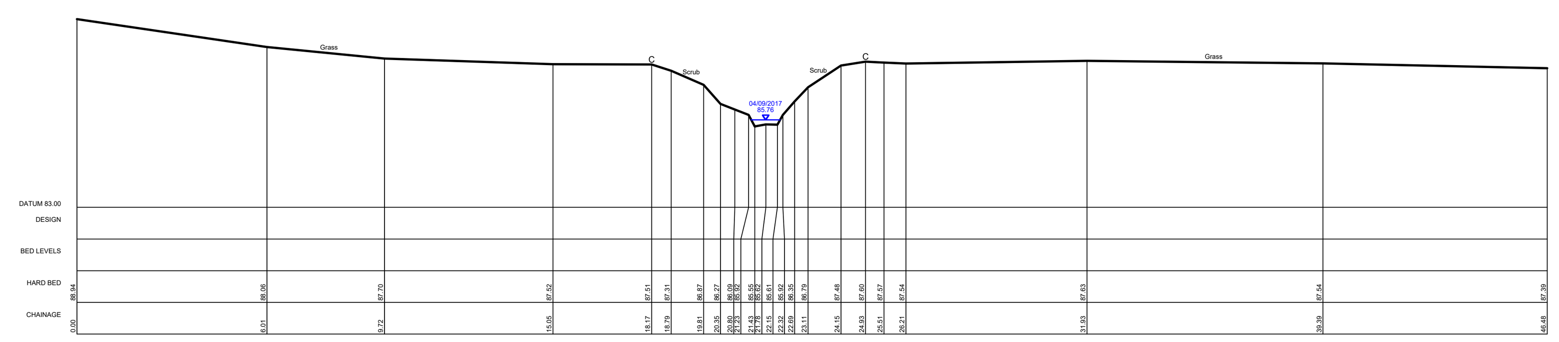
Drawing Status

INFORMATION

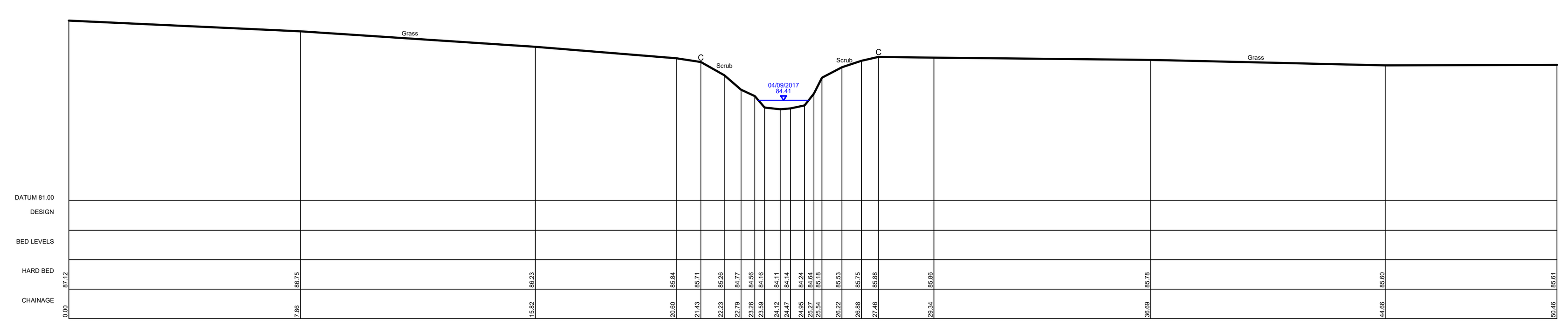
Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMM-BWB-00-03-DR-G-001	S2	P1



TBR1.009
338624.14mE 333531.36mN Brg 130
Chainage 1487.9m
Open Channel



TBR1.011
338372.82mE 333259.6mN Brg 149
Chainage 1867.7m
Open Channel



TBR1.010
338546.84mE 333441.46mN Brg 142
Chainage 1611.3m
Open Channel

Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
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7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
Flow direction and pipe diameter (0.25)
Station and Name
Monitoring Borehole (BH 1)
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
Spot Level (50.00)
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	15.09.17	First Issue	LP	DS

Issues & Revisions

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Client
BURBURY INVESTMENTS LTD.

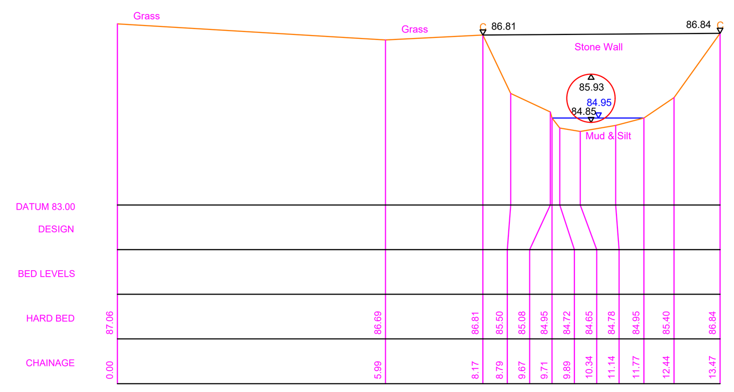
Project Title
ELLESMERE MARINE

Drawing Title
WATERCOURSE SURVEY SHEET 4 OF 4

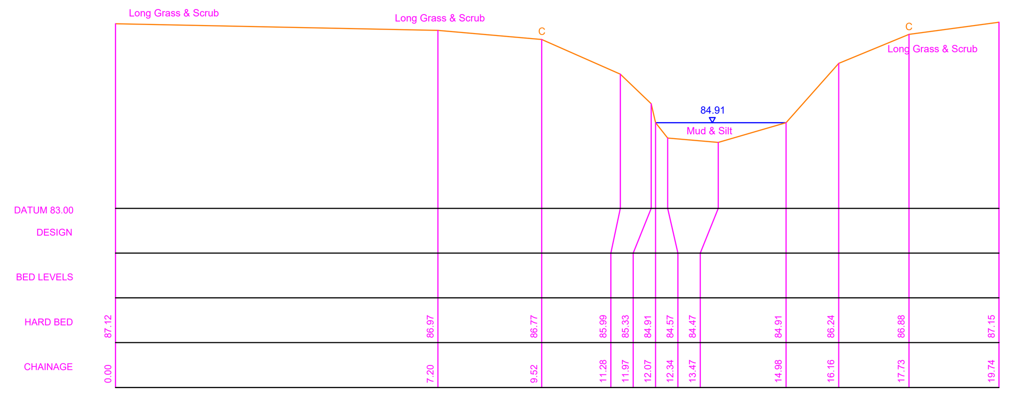
Drawn:	L.Padmore	Reviewed:	D.Smith
BWB Ref:	BMW 2025	Date: 15.09.17	Scale@A1: 1:200

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMM-BWB-00-04-DR-G-001	S2	P1



R1_00000
339608.00Em 334060.87Nm BEARING 339Dgr
0.230 M
Culvert
24/03/2022



R1_00049
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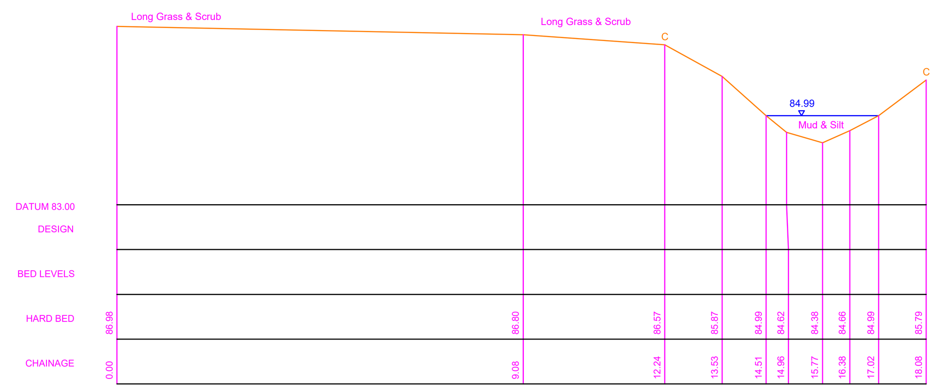
47.928 M
Open Channel
24/03/2022



R1_00130
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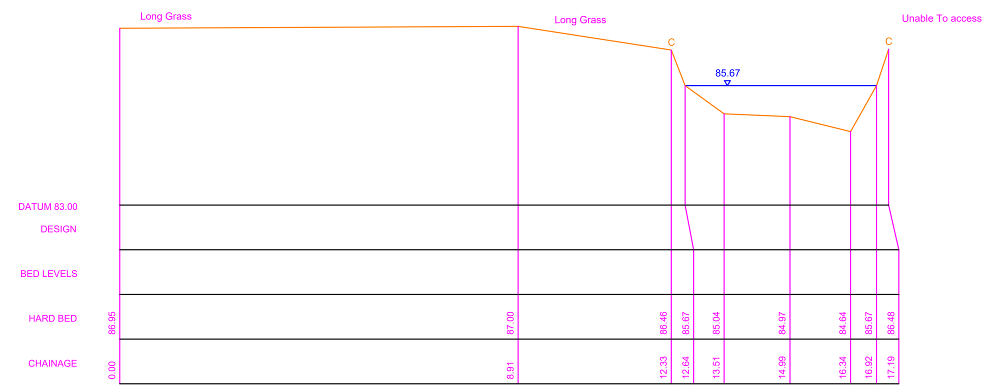
129.066 M
Open Channel
24/03/2022



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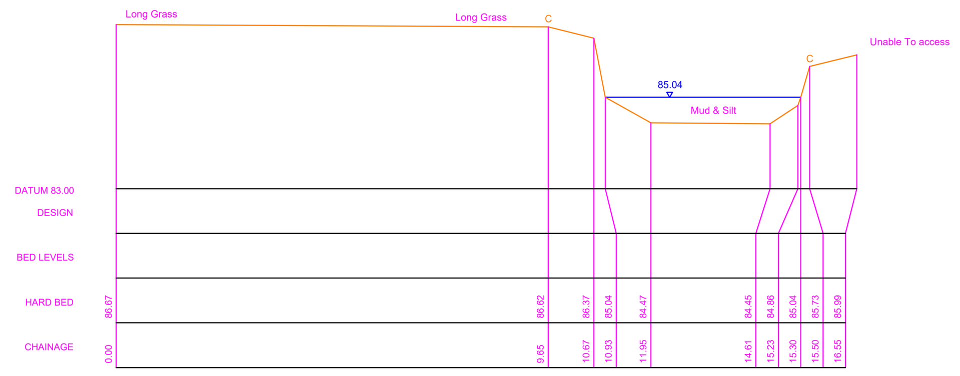
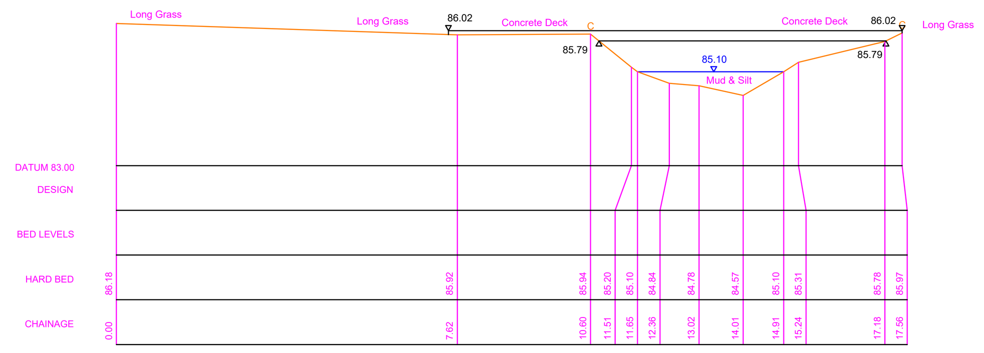
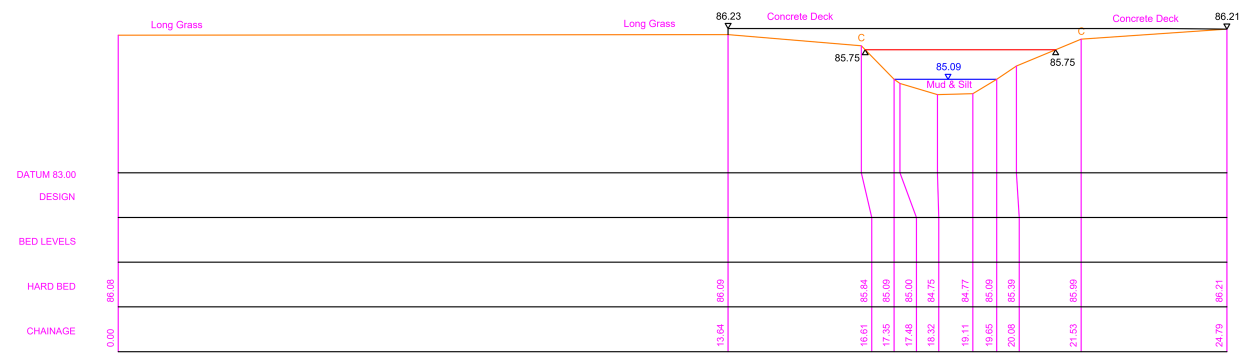
201.607 M
Open Channel
24/03/2022



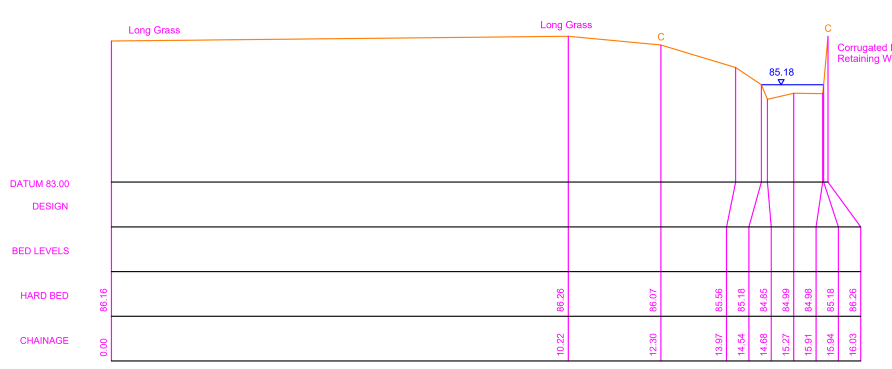
R1_00272
339835.51Em 334208.62Nm BEARING 320Dgr
271.661 M
Open Channel
24/03/2022



R1_00312
339864.73Em 334234.28Nm BEARING 321Dgr
310.764 M
Access Bridge
24/03/2022



R1_00316
339871.15Em 334232.85Nm BEARING 321Dgr
314.671 M
Access Bridge
24/03/2022



R1_00345
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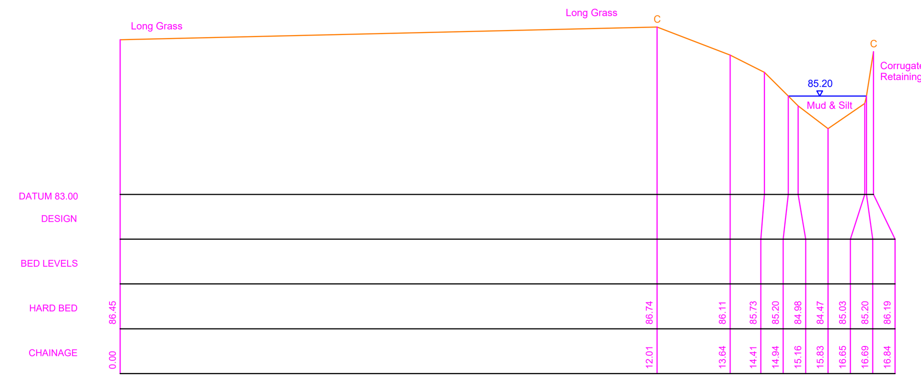
344.277 M
Open Channel
24/03/2022



R1_00372
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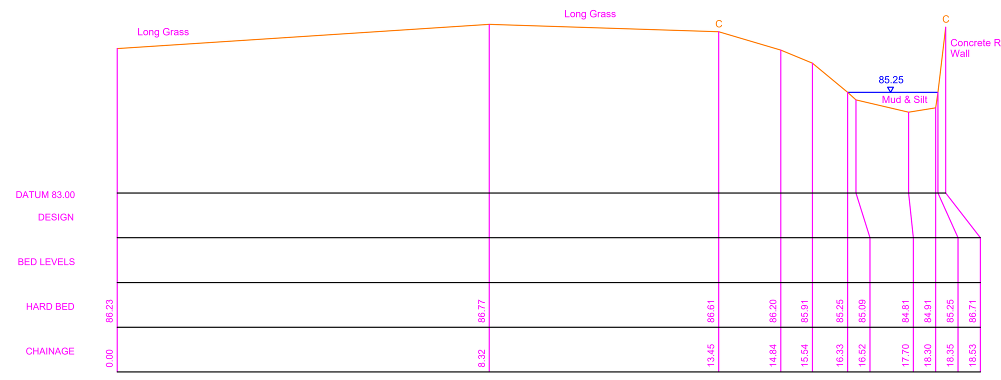
371.128 M
Open Channel
24/03/2022



R1_00401
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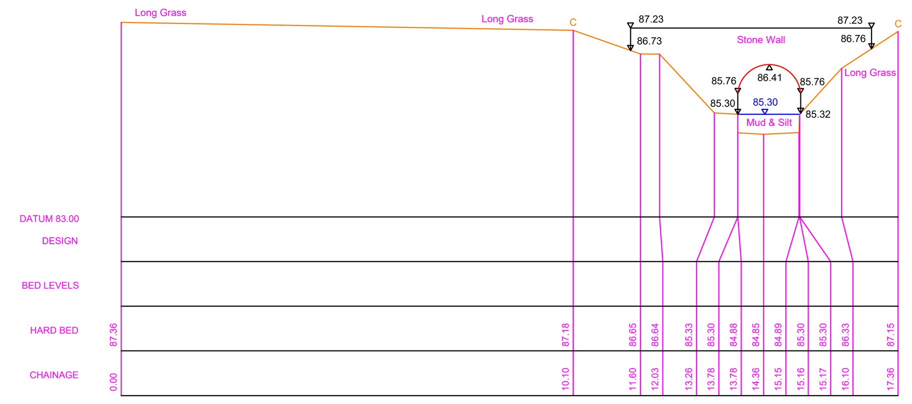
399.874 M
Open Channel
24/03/2022



R1_00452
339973.57Em 334323.75Nm BEARING 319Dgr
451.238 M
Culvert
24/03/2022

Notes

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8. OS license number: 100022432

Key Plan

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
0.25 Flow direction and pipe diameter
Station and Name
BH 1 Monitoring Borehole
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
+50.00 Spot Level
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	28.03.22	First Issue	IR	DS

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Client
BURBURY INVESTMENTS LTD

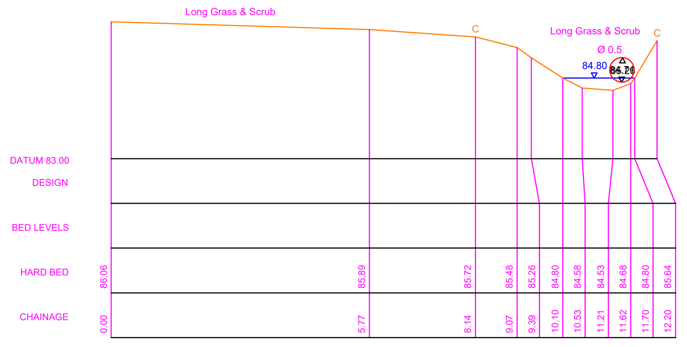
Project Title
ELLESMERE MARINA SHROPSHIRE

Drawing Title
WATERCOURSE SURVEY REACH 1 SHEET 1 OF 4

Drawn:	I.Riley	Reviewed:	D.Smith
BWB Ref:	BMW 2025	Date: 28.03.22	Scale@A0: 1:100

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMS-BWB-01-ZZ-M2-G-0060	S2	P1



R2_00000
339464.80Em 334077.51Nm BEARING 277Dgr
0.356 M

24/03/2022

Notes

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Key Plan

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities

120 Contour Lines
Inspection Chamber
0.25 Flow direction and pipe diameter
1 Station and Name
BH 1 Monitoring Borehole
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
+50.00 Spot Level
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
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CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
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FL	Floodlight			WO	Wash Out

P1	28.03.22	First Issue	IR	DS
Rev	Date	Details of issue / revision	Drw	Rev

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Client

BURBURY INVESTMENTS LTD

Project Title

ELLESMERE MARINA SHROPSHIRE

Drawing Title

WATERCOURSE SURVEY REACH 2 SHEET 2 OF 4

Drawn:	I.Riley		Reviewed:	D.Smith	
BWB Ref:	BMW 2025	Date:	28.03.22	Scale@A0:	1:100

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMS-BWB-02-ZZ-M2-G-0060	**S2**	**P1**

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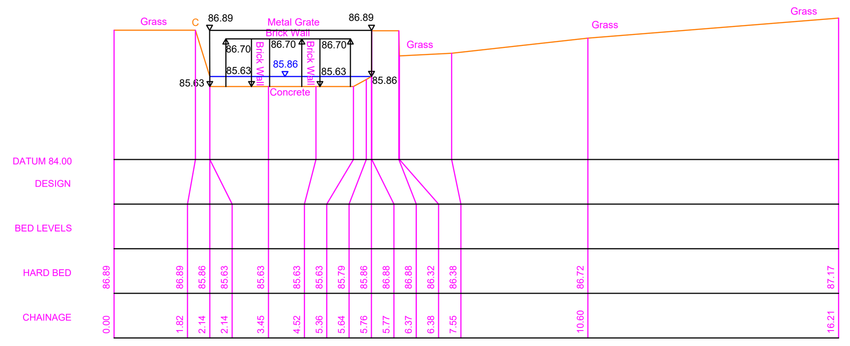
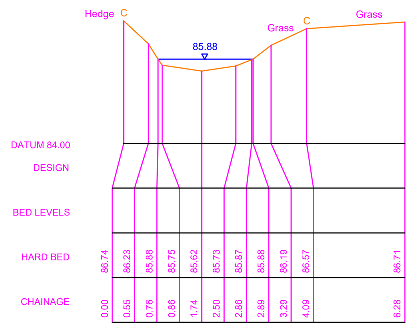
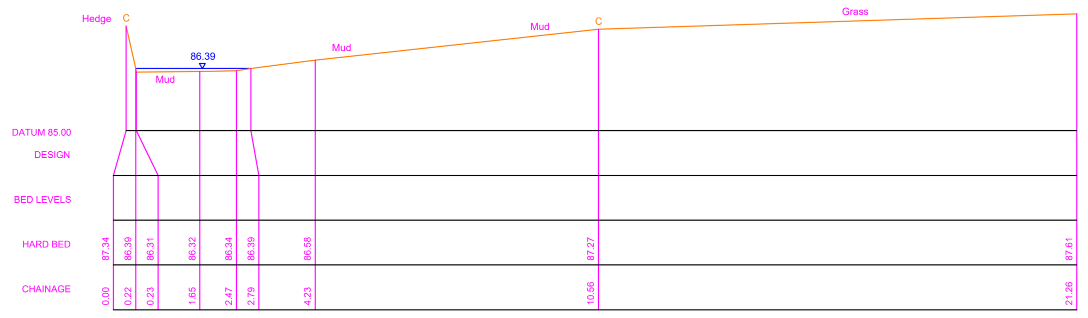


NB_00000
338841.37Em 333925.66Nm BEARING 281Dgr
0.484 M
Culvert
25/03/2022



NB_00010
338844.01Em 333934.14Nm BEARING 308Dgr
10.282 M

25/03/2022



NB_00157
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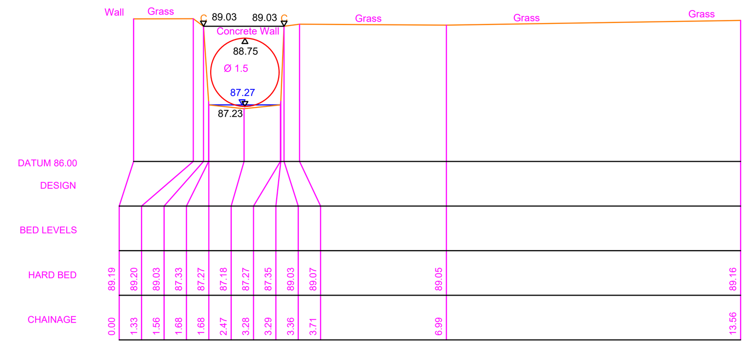
157.453 M

25/03/2022



NB_00410
339022.83Em 334285.52Nm BEARING 306Dgr
409.779 M
Culvert
25/03/2022

Notes

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Key Plan

Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
0.25 Flow direction and pipe diameter
1 Station and Name
BH 1 Monitoring Borehole
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
+50.00 Spot Level
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
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CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
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Rev	Date	Details of issue / revision	Drw	Rev
P1	28.03.22	First Issue	IR	DS

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Client
BURBURY INVESTMENTS LTD

Project Title
ELLESMERE MARINA SHROPSHIRE

Drawing Title
WATERCOURSE SURVEY REACH 3 (NEWENS BROOK) SHEET 3 OF 4

Drawn:	I.Riley			Reviewed:	D.Smith
BWB Ref:	BMW 2025	Date:	28.03.22	Scale@A0:	1:100

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMS-BWB-03-ZZ-M2-G-0060	S2	P1

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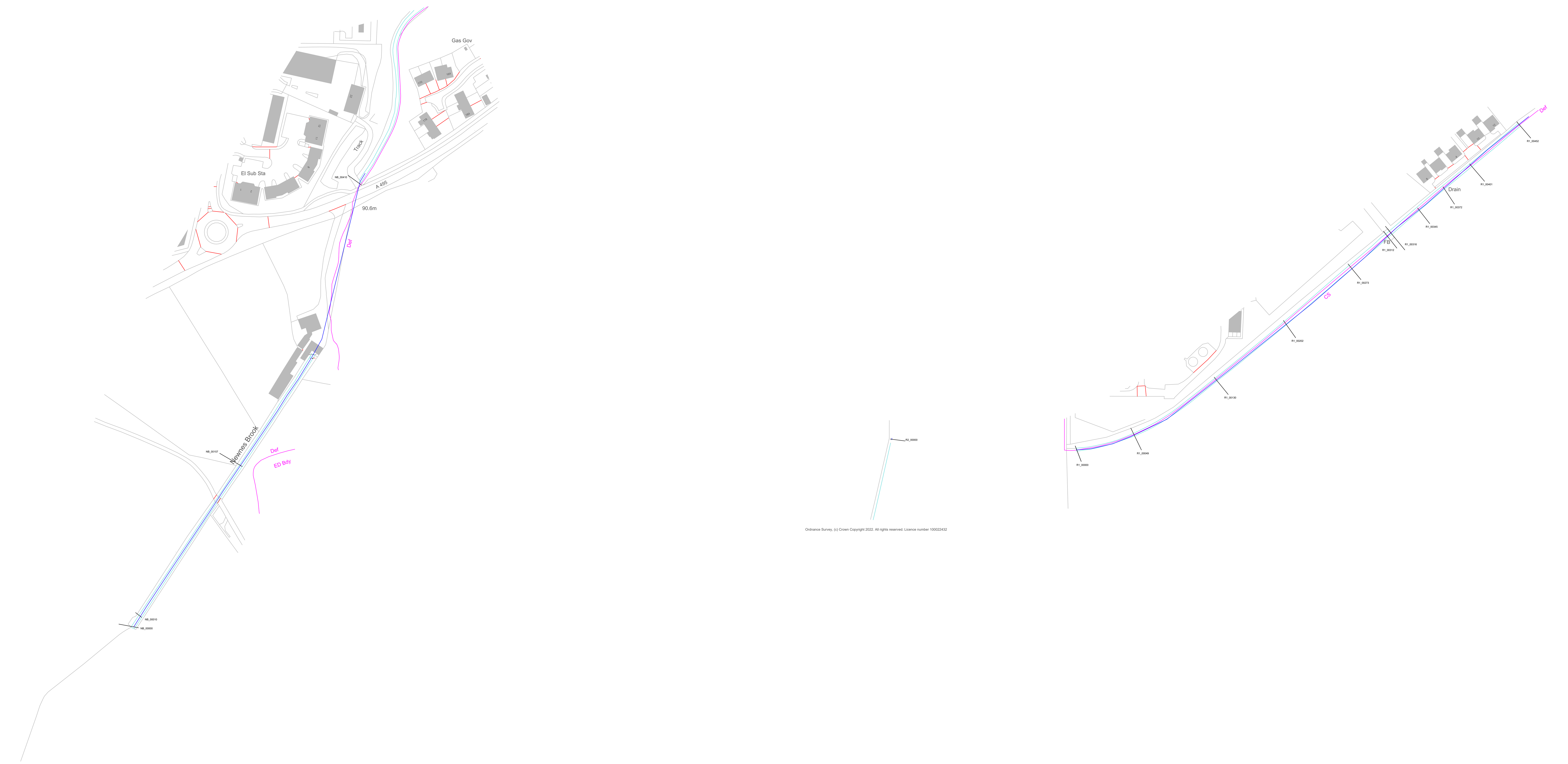

Notes

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Surveyed Buildings
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Top of Kerb
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0.25 Flow direction and pipe diameter
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Body of Water from OS
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Surface Water Drainage Line

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CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	28.03.22	First Issue	IR	DS

Issues & Revisions

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A CAF GROUP COMPANY

■ Birmingham | 0121 233 3322
□ Leeds | 0113 233 8000
□ London | 020 7407 3879
□ Manchester | 0161 233 4260
□ Nottingham | 0115 924 1100
www.bwbconsulting.com

Client

BURBURY INVESTMENTS LTD

Project Title

ELLESMERE MARINA SHROPSHIRE

Drawing Title

EXISTING WATERCOURSE LAYOUT SHEET 4 OF 4

Drawn:	I.Riley	Reviewed:	D.Smith
BWB Ref:	BMW 2025	Date: 28.03.22	Scale@A0: 1:100

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
EMS-BWB-04-ZZ-M2-G-0060	S2	P1

Appendix 4: Topographical Surveys

NOTES

GENERAL NOTES :–

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boll – bollard
bos – bottom of shaft
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c/box – control box
catv – cable television
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con – conifer
cr – cable riser
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OSBM – ordnance survey bench mark
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SHEET LAYOUT :–

A0–SHEET 38793/1
A0–SHEET 38793/3
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A0–SHEET 38793/4

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CPT
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HAND PIT
WINDOW SAMPLE

ELECTRIC CABLE
W – WATER PIPE
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UTILITY NOTES

NORTH

0 5 10 20 30 40 50

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Date	JULY 2021
Scale	1:500@A0
Dwg No	38793 /1
Surveyor	J.D
Checked	L.R

Revisions

TOPOGRAPHICAL (LAND) SURVEYORS / UTILITY SURVEYORS
BUILDING MEASUREMENT SURVEYORS / 3D LASER SCANNING

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constructionLine
QUALITY ASSURED BS EN ISO 9001:2008 QUAY AUDIT LTD ASCB(E)
THE SURVEY ASSOCIATION

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www.midlandsurvey.co.uk

Client ROBERTS LIMBRICK LTD

Project 5614 LAND AT ELLESMERE BURBURY

Title TOPOGRAPHICAL SURVEY

Date JULY 2021

Revisions

Scale 1:500@A0

Dwg No 38793 0

Surveyor J.D

Checked L.R

TOPOGRAPHICAL (LAND) SURVEYORS / UTILITY SURVEYORS
BUILDING MEASUREMENT SURVEYORS / 3D LASER SCANNING

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Additional below ground structures or obstructions not shown on this drawing may be present. Reference should be made to historical plans and as–built drawings. Excavations in the vicinity of services should be carried out with due diligence ref: HSG47 document avoiding dangers from underground services

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TSA Standards – "Even an appropriate and professionally executed survey may not be able to achieve a 100% detection rate."

UTILITY NOTES

NORTH

0 5 10 20 30 40 50

MIDLAND SURVEY LTD

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Client ROBERTS LIMBRICK LTD

Project 5614 LAND AT ELLESMERE BURBURY

Title TOPOGRAPHICAL SURVEY

Date	JULY 2021	Revisions
Scale	1:500@A0	
Dwg No	38793 0	
Surveyor	J.D	
Checked	L.R	

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