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Forder Valley Community Park

Flood Risk Assessment

BALFOUR BEATTY

Project number: 60535194

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Quality information

Prepared by	Checked by	Verified by	Approved by
Harry Beedham Graduate Engineer	Paul Whitham Principle Engineer	Edward Hobbes Senior Engineer	Jason Langley Regional Director

Revision History

Revision	Revision date	Details	Authorized	Name	Position

Distribution List

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Prepared for:

BALFOUR BEATTY

Prepared by:

Harry Beedham
Graduate Engineer
T: 01392 663200
E: harry.beedham@aecom.com

AECOM Limited
Belvedere House
Woodwater Park, Pynes Hill
Exeter EX2 5WS
United Kingdom

T: +44 1392 663200
aecom.com

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Executive Summary

AECOM has been commissioned by the Client, Balfour Beatty to undertake a site-specific Flood Risk Assessment (FRA) for the proposed community development at Forder Valley Community Parks, Plymouth.

PCC proposes to develop a site in North Plymouth, between Derriford and the A38. This FRA has been prepared to support the planning application for a Community Park development. This FRA is specifically regarding the Forder Valley Community Parks cycle and walk ways which are to be developed, as part of the link road project.

The Community Parks site is located to the south of Derriford, north of Eggbuckland bordering the B3431 and northwest of Leigham. This area is currently occupied by a community park, with Forder Stream running along the southern boundary, and Bircham Stream to the East.

Government policy with respect to development and flood risk in areas in England is contained within the Department for Communities and Local Government document National Planning Policy Framework (NPPF)[1] and its accompanying Technical Guidance published in 2012. This site-specific FRA has been prepared in accordance with those documents and in consultation with the Environment Agency (EA), Plymouth County Council and South West Water.

Assessment of existing flood risk sources including fluvial, tidal, groundwater, sewers, surface water runoff and overland flow was carried out as per the below table:

Type of Flooding	Sources of Flooding	Flood Risk
Fluvial	Bircham Stream Forder Stream	Medium
Groundwater	Underlying geology and groundwater levels	Low
Sewers	Foul Water Sewers	Very Low
Surface water	Runoff from surrounding developed land	Medium
Reservoir	None	Very Low

A surface water drainage strategy will be proposed to manage surface water runoff from the proposed paths during rainfall events.

This FRA demonstrates that the flood risk to the site is low to medium for the existing and post-development situation. The flood risk offsite will not be increased by the Proposed Development and the residual risk to the site and elsewhere from a number of flood sources will either be unaffected or marginally improved by the proposals.

[1] Communities & Local Government (2012) '*National Planning Policy Framework'* Department for Communities and Local Government: London

1. Introduction

1.1 Background

AECOM has been commissioned by Balfour Beatty to undertake a site-specific Flood Risk Assessment (FRA) for the proposed Community Parks redevelopment/improvements in Forder Valley, Plymouth. The proposed development is part of the wider Seaton Neighbourhood and Forder Valley Link Road development. As part of this, cycle and footpaths are to be constructed/improved within the Forder Valley Community Parks ("the Site") with the inclusion of new bridges over the Forder Valley and Bircham streams. This FRA is to support a detailed planning application, required due to the size of the site and the requirement for development within Flood Zone 3 (see Section 4).

The Site is located at grid ref: 250300E 058600N. The area currently consists of the community park, with Derriford hospital to the north, Derriford Business Park to the west, residential areas to the east and the B3413 to the south. A location plan indicating proposed cycleway routes and bridges in relation to the flood risk zones and the wider-development area is shown in Figure 1-1.

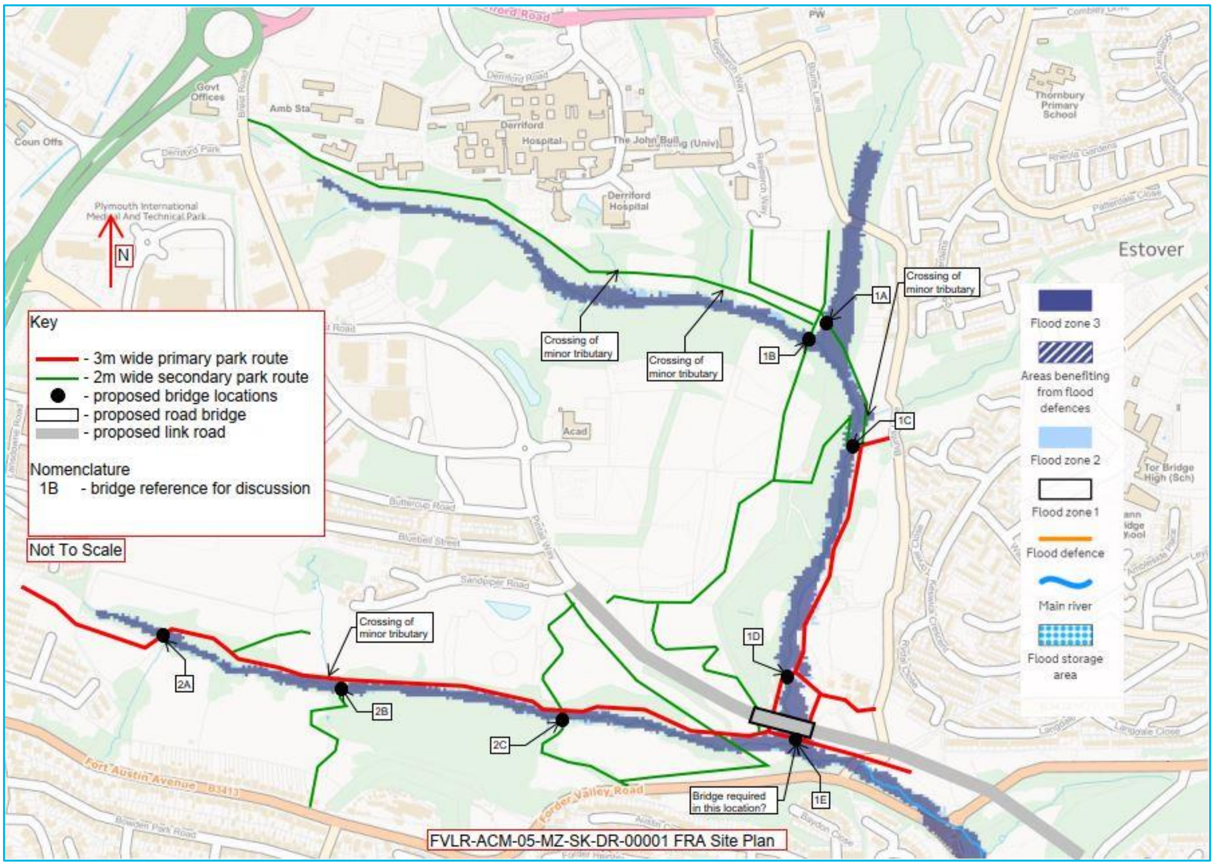

Figure 1-1: Site location plan and flood zones

The drainage strategy for the site contained within this report looks at management of surface water and existing flood risk, as well as setting parameters for the design and location of bridges/crossing points over the Forder Valley and Bircham Streams.

This document is a stand-alone FRA for the Community Park area only, although it also considers flood risk to and from the surrounding area, particularly with regards to the proposed Link Road and Seaton Neighbourhood drainage strategies/designs.

1.2 Planning Policy

1.2.1 National Planning Policy Framework

The National Planning Policy Framework (NPPF) sets out the Government's planning policies for England and how they are expected to be applied. The policy aims to avoid inappropriate development by directing it away from the areas that are at highest risk. Where development is necessary within the floodplain, it must be demonstrated to be safe without increasing flood risk elsewhere.

Planning policy states that a site-specific FRA is required for development proposals that are located within Flood Zone 2 and 3. A site-specific FRA is also required for development proposals greater than a hectare located in Flood Zone 1.

A site-specific FRA should identify and assess the risks of all sources of flooding to and from the development and demonstrate how these flood risks will be managed so that the development remains safe for its lifetime, taking climate change into account.

1.2.2 Flood Zone Definition

The Technical Guidance to the NPPF defines the flood risk zones that are published by the Environment Agency, which are as follows:

- Flood Zone 1 - the low probability zone which is defined as having a less than 0.1% (or 1 in 1000 year) probability of flooding each year;
- Flood Zone 2 – the medium probability zone which is defined as having between 0.1% and 1% (or between 1 in 1000 and 1 in 100 year) probability of fluvial flooding or between 0.1% and 0.5% (or between 1 in 1000 and 1 in 200 year) probability for flooding from the sea each year;
- Flood Zone 3a – the high probability zone which is defined as having a 1% or greater (or 1 in 100 or greater) probability of fluvial flooding, or a 0.5% or greater (1 in 200 or greater) probability of flooding from the sea each year;
- Flood Zone 3b – Functional Floodplain which is defined as land where water has to flow or be stored in times of flood.

1.2.3 Sequential Test

The NPPF aims are to ensure that flood risk is taken into account at all stages of the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas of highest risk. On the Council scale this is achieved through the application of the Sequential Test by the Local Planning Authority (LPA). The Sequential Test encourages LPAs to steer development to areas of lowest flood risk on a council wide level and only develop in flood risk areas where absolutely necessary. The LPA should apply the Sequential Test based on information presented in their Strategic Flood Risk Assessment (SFRA). The NPPF Sequential Test evaluates the risk of flooding, based on Environment Agency Flood Zones, against the vulnerability of the proposed development.

Table 1: Flood Risk Vulnerability and Flood Zone Compatibility

Flood risk vulnerability classification		Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood zone	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test required	✓	✓
	Zone 3a	Exception Test required	✓	×	Exception Test required	✓
	Zone 3b functional floodplain	Exception Test required	✓	×	×	×

1.2.4 Exception Test

Where new development is necessary in such areas, policy aims to make it safe, without increasing flood risk elsewhere, and where possible, reducing flood risk overall through application of the NPPF's Exception Test. The Exception Test allows consideration of the wider sustainability benefits of a development to be considered to justify development in a higher risk flood zone. To ensure that the proposed development meets the requirements of the Exception Test (NPPF):

a) it must be demonstrated that the development provides wider sustainability benefits for the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared; and

b) a site-specific Flood Risk Assessment must demonstrate that 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.

1.2.5 Plymouth and South West Devon Joint Local Plan 2014-2034

The "Report on the Examination of the Plymouth and South West Devon Joint Local Plan 2014-2034"[2] was published in 2018, and sets out the long-term spatial vision and policies for the area up to 2034. Sections 209 through to 213 regard climate change, flooding and coastal management as follows:

209. The Plan seeks to ensure that development and use of land will contribute to the mitigation of, and adaptation to, climate change. In combination with other policy requirements in the Plan, this is sought through the delivery of low carbon development, renewable and low carbon energy and community energy and the management of flood risk, water quality and coastal change.

210. To ensure that Policy DEV34 and its supporting text provides a positive strategy for seeking the delivery of low carbon development, MM54 makes several necessary changes. This includes identifying a carbon reduction target for the Plan area and encouraging the increased use of decentralised energy. For effectiveness the modification also seeks development that reduces the heat loss area and optimises access to natural light. The insertion of the words 'where there is a future network planned' in relation to connections to district energy networks is also necessary for clarity.

211. Policy DEV35 seeks to increase the use of renewable and low carbon energy. Various modifications in MM55 add clarity to the policy. This includes ensuring that proposals are assessed individually and cumulatively in terms of any likely impact on the natural environment and heritage assets and that they demonstrate how they have been informed by public consultation.

[2] https://www.plymouth.gov.uk/sites/default/files/PSWDJLPFinalReport.pdf - Accessed September 2019

212. The other policies on community energy, flood risk, water quality and coastal change management are sound. Plymouth and South West Devon Joint Local Plan, Inspectors' Report 18 March 2019 37 Conclusions on the environment

213. In conclusion, subject to the above MMs, the Plan's strategies and policies for the historic environment, natural environment, minerals resources, climate change, flooding and coastal management are soundly based.

1.2.6 The Plymouth Plan[3]

The Plymouth Plan sets guidance for the strategic planning of the long-term future of the city, including the developmental strategy for which The Site falls under. Policy GR08 deals with flood risk:

"*The City will manage risk in association with flooding by: Working with South West Water, the Environment Agency and other relevant organisations including asset owners to ensure that Plymouth's flood defence, coast protection, drainage and sewerage infrastructure is sustainable and meets the requirements placed upon it by population growth and climate change. Flood defence, water supply, surface water and waste water infrastructure requirements should be put in place in tandem with planned growth to avoid adverse social, economic and environmental impacts.*

Working with the Environment Agency and South West Water to align priorities for the efficient and effective management of tidal, fluvial, surface water and sewer flood risk, and to improve and ensure the effective functioning of the city's sewerage and drainage infrastructure.

Maintaining an emergency response plan, sufficient to address the risks to life and livelihood from extreme weather events

Using planning powers to ensure that development takes place in appropriate locations and with proper regard to flood risk

5.40 Changes in weather patterns could result in an increase in flooding in some parts of the city. Intense rainfall events are expected to continue to increase in frequency in the coming decades throughout the UK. Sea levels are rising and will continue to do so, and storms are expected to increase in frequency and severity. Flooding can come from a range of sources such as tidal inundation, flooding from rivers after heavy rainfall and flash flooding caused by rainfall running off hard surfaces or from fields in rural areas. Flooding can overload 64 sewerage and drainage systems and increase the risk of pollution and nuisance. It is important that flood risk is carefully considered, including how new development is designed so as not to increase vulnerability, where areas are vulnerable, risks should be managed through suitable adaptation measures. The JLP identifies how the policy will be supported through the planning system.

5.41 National flood risk mapping indicates that there are more than 900 properties at high risk of flooding (Flood Zone 3) in Plymouth from the sea or main rivers. Over 3,000 properties are at risk from surface water flooding. There is also a risk of damage to key transport infrastructure and services that would have a significant economic cost. Plymouth's delivery plan for managing local flood risks includes maps of risk areas for sea, fluvial and surface water flooding and information on strategic flood risk management infrastructure requirements. The South Devon and Dorset Shoreline Management Plan has a policy of 'hold the line' for the majority of Plymouth's coast, having considered and rejected the alternative options of no active intervention and retreating defences further inland.

5.42 In order to mitigate these risks, the policy will help to: Reduce the amount of rainwater reaching the sewers and water courses in Plymouth. Improve the capacity of particular water courses and sewers, so that flood risk is significantly reduced during storm events. Restrict the volume and nature of development in risk areas, and ensure any development in these areas is resilient to flooding and coastal erosion/storm damage. Secure financial contributions to the maintenance and improvement of strategic drainage infrastructure, fluvial and tidal flood defences, and erosion defences."

[3] https://www.plymouth.gov.uk/sites/default/files/PPRefresh2.pdf - Accessed September 2019

1.2.7 Plymouth Local Flood Risk Management Strategy (2019)[4]

Guidance for flood risk management in Plymouth is provided by the LFRMS, and includes guidance for planning, designing and management of flooding and surface water drainage, including requirements for the construction phase. The drainage hierarchy to be considered is given, below.

- Discharge to a waterbody (if available and with sufficient capacity)
- Infiltration
- Discharge to a surface water sewer, highway drain or culverted watercourse with attenuation as required
- Discharge to a combined sewer given written permission from the Sewerage Undertaker

The site is within the PCC Critical Drainage Area (CDA). The on-site surface water discharge rate for any new development area should be managed safely for the 1% AEP +40&CC event (1 in 100 year event with an additional 40% climate change allowance). Off-site surface water discharge rate from the proposed development should be restricted to the maximum 10% (1 in 10 year return period) greenfield runoff rate for positive systems.

1.3 Site Description and Topography

The Community Park area covers approximately 70ha and currently contains land comprising greenfield and wooded areas, streams, farmland and nature reserves. The Forder Valley cycle route follows the route of an historic tram way. The developed cycle route areas within the Community Park (including earthworks, fencing etc.) cover approximately 17.5ha (7.3ha for the Bircham area, 10.2ha for the Forder Valley area). Currently, a residential development is taking place adjacent to the site with a link road and bridge to be constructed through the site, which are the subject of separate FRAs and planning submissions.

The proposed routes are shown on the Drainage Strategy Plan (FVLR-ACM-05-MZ-DR-DR-10019) in Appendix A and outlined in Figure 1-2.

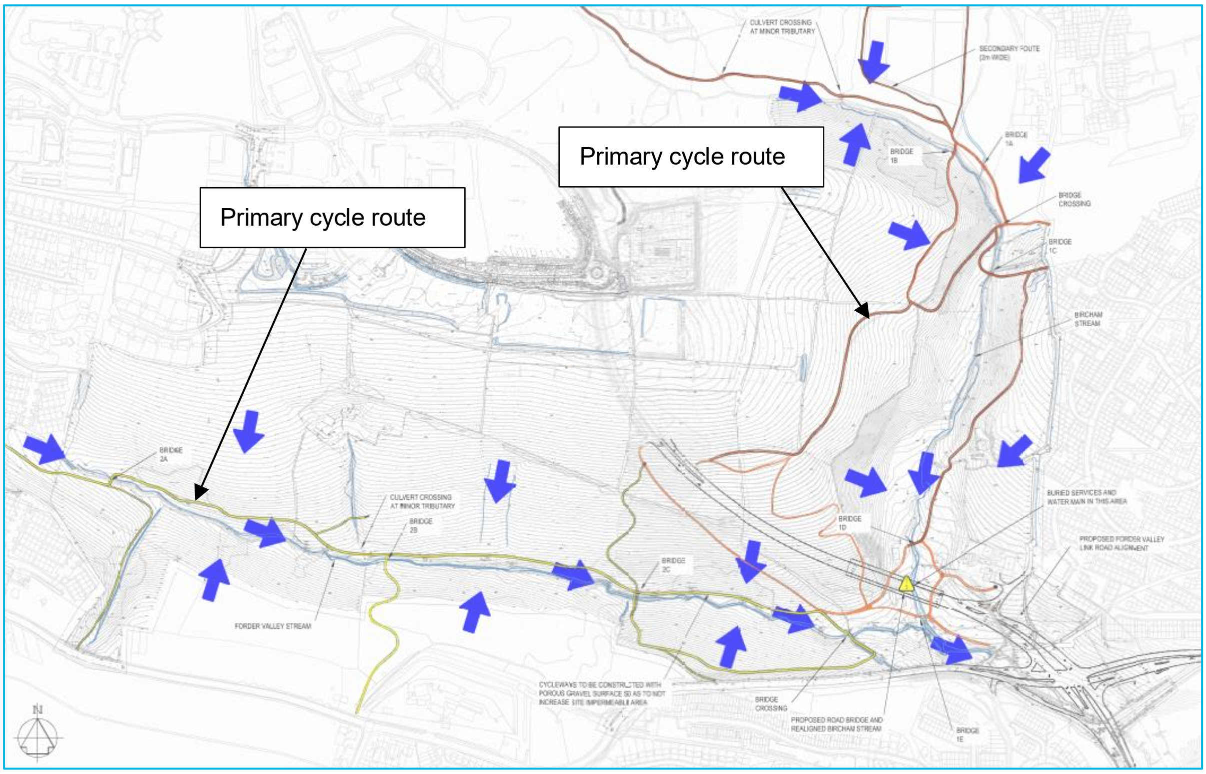

Figure 1-2: FVLR Scheme, including Cycle Routes on OS and Topographical Survey.

[4] https://www.plymouth.gov.uk/sites/default/files/LFRMSPart2Specifications2019Final.pdf - Accessed September 2019

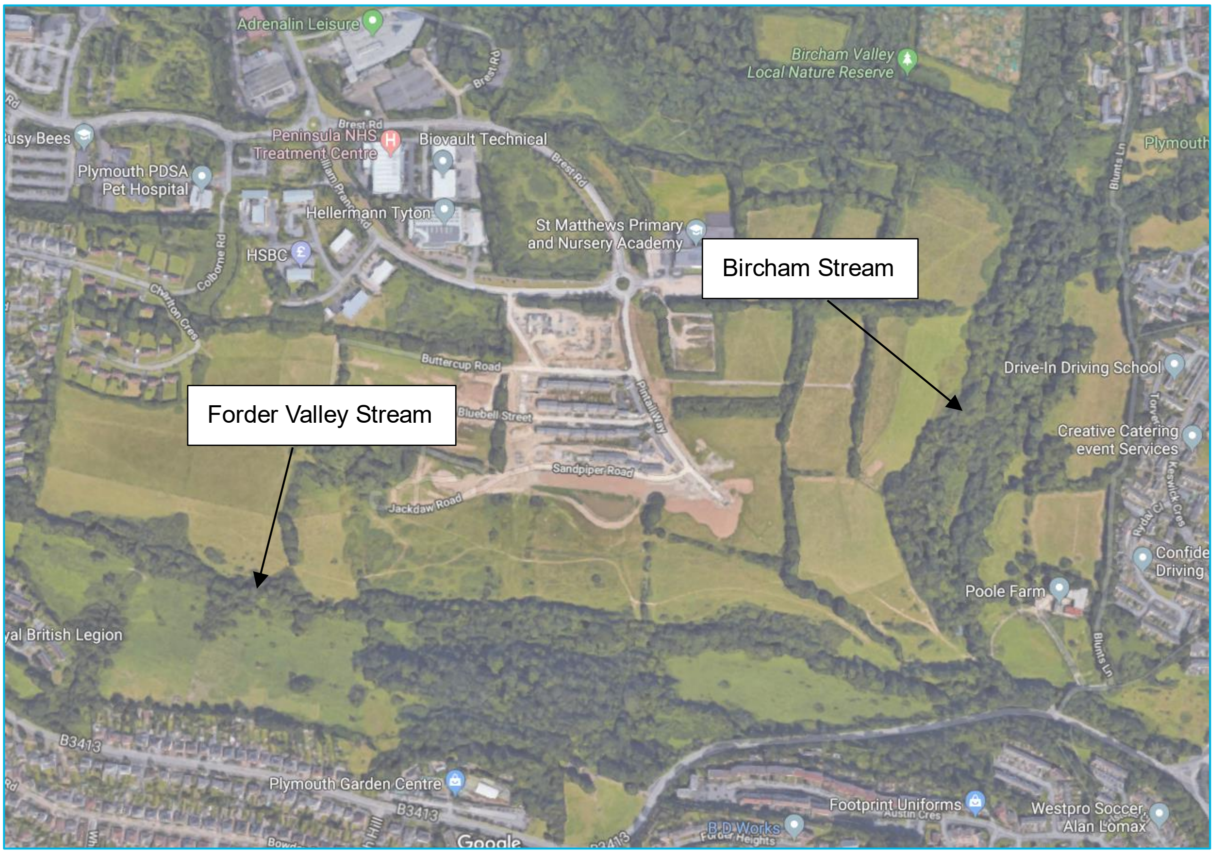

Figure 1-3: Satellite imaging of existing Site

The principal watercourses within the vicinity of the Site are the Forder Valley Stream (west to east) and the Bircham Stream (north to south). Each stream is fed by a number of smaller tributaries within the site area. Bircham Stream originates 1km to the north west of the proposed road bridge, and throughout the site has a relatively steep catchment, with an area of approximately 2.7km². At approximately 70m upstream to the confluence between this stream and the Forder Stream, a culvert runs beneath the track. In proximity to the upstream of the confluence lies a concrete footbridge which crossed both the watercourses. Just upstream of the Bircham Stream and Forder Valley Stream confluence there is an existing concrete footbridge per Figure 1-4.

Figure 1-4: Footbridge, upstream of Forder/Bircham Stream confluence

The Forder Stream has a relatively steep catchment throughout the site, with an area of approximately 9km². Part of this stream is culverted approximately 150m upstream of the confluence with Bircham Stream. At approximately 55m downstream of the confluence there exists a small stone arch bridge beneath Blunts Lane. Beneath Novorossiysk Road the stream is further culverted by two 1.25m diameter concrete pipe culverts protected by a trash screen on the upstream face. After this culvert, the watercourse discharges to the River Plym in approximately 2.4km to the south east.

The topography falls generally from west/northwest to east/southeast, forming a system of valleys with channels and flood plain for the Forder Valley and Bircham Streams. The site falls from approximately 80mAOD at the head of the Forder Valley Stream for 1.4km, and 110mAOD at the head of the Bircham Stream for 1.6km, to approximately 25mAOD at their confluence – giving longitudinal gradients of 1:25 and 1:20, respectively. The Forder Valley then falls to approximately 21mAOD at the south eastern limit of the Community Park area, by the B3432, Novorossiysk Road, with a longitudinal gradient of approximately 1:75. Extracts of the topographical survey are included in Appendix A.

1.4 Site geology and hydrogeology

The British Geological Survey (BGS) data[5] has identified the bedrock beneath the site as varying; Upper Devonian Slate under the east of the site, with Saltash Formation Slate and Siltstone and bands of Torpoint Formation Mudstone and Siltstone under the west of the site. Superficial deposits consist of gravel, clay, silt and sand and are present adjacent to stream locations. The area is designated a Secondary A Aquifer.

Groundwater used for drinking water is protected by the Environment Agency. The Environment Agency classifies zones known as Source Protection Zones (SPZ) around potable groundwater abstraction points, designed to limit potentially polluting activities. The Environment Agency website shows that the site does not overlie a SPZ.

1.5 Study Aims and Objectives

The overall objective of this study was to carry out an FRA that meets the requirements of the NPPF. The study is required to assess all aspects of flood risk to the proposed development, the potential impacts of the development on people and property elsewhere within the catchment and identify possible mitigation measures to ensure that the development is safe in the event of a flood. To achieve this aim, the following key actions are to be undertaken:

- Undertake consultation with the Lead Local Flood Authority (LLFA – Plymouth City Council);
- Review topographical and flood risk data to identify the existing flood risk posed to the site from all sources;
- Assess the residual flood risk post-development;
- Review and assess the surface water runoff generated at the site; and
- Identify suitable mitigation measures to protect the development site against flooding.

1.6 Scope of Works

In order to meet the above objectives, the following scope of work and tasks were undertaken:

- Task 1: Data Collection. AECOM has collected relevant available information on the nature of the flooding at the site. The Applicant has provided information about the proposed development layout and design and AECOM are the lead designer/consultant for the scheme. FRA data for previous planning submissions for the wider development were also reviewed.
- Task 2: Identification of Current and Post-Development Flood Risk. The existing and post-development flood risk posed to the site was assessed from the data that was collected in Task 1. The assessment identifies the flood risk from all potential sources of flooding and includes consideration of the impact of climate change on flood risk.
- Task 3: Assessment of Site Drainage. AECOM developed, using current good practice methods, a site-specific drainage strategy to mimic the existing drainage regime.

This strategy commits to meeting the requirements of the NPPF and will aim to meet the requirements of the EA.

1.7 Data Collected

Table 2 lists the data that has been collected as part of this assessment. Comments on the source and the nature of the data are also provided.

[5] http://mapapps.bgs.ac.uk/geologyofbritain/home.html - Accessed September 2019

Table 2: Data collected

Purpose	Data and Source	Comments
Identification of Site Location	Ordnance Survey Map	Identifies the position of the site and local hydrological features
Identification of Flood Risk	Topographical Survey	Existing site levels and topography
	Development details	Information on the layout of the proposed development
	Environment Agency indicative flood zone maps and long term flood risk maps	Risk of flood from tidal and fluvial sources, surface water and from reservoirs
	Correspondence with PCC	Setting parameters for infrastructure in the flood plain and drainage features
	Correspondence with South West Water	Asset plans identifying public sewers nearest to the site
	Flood Risk Assessments and Hydraulic Modelling	Work undertaken for previous planning applications for the wider development area
	Ground Investigation report	Identifies bedrock type and groundwater levels

2. Existing Flood Risk

This section of the report identifies the existing risks from the different forms of flooding identified in NPPF.

2.1 Historic Flood Records

According to EA flood records (Appendix D), there was flooding from unknown sources in 1950. Flood records become more frequent from 1990, possibly because of improved reporting, but also due to development in the area. Flood risk increased as a consequence of developments to Forder Valley Road in 1984 which impeded the stream flows. Further development to Derriford (north of the Site) has also increased the flooding risk and flash flooding has occurred around points of restricted flow when the watercourse was overloaded. Flooding occurred to two properties at Wilburt Road (private road off of the Forder Valley Road downstream and to the south east of the site). In 1989 a large culvert was installed under Wilburt Road which partially alleviated the restriction.

There have been no historic records of flooding to the existing Novorossiysk Road to the south east of the Site.

2.2 Fluvial/Tidal Flood Risk

Tidal flood risk does not affect the site due to the local topography and the height difference and downstream distance to the River Plym, approximately 1km from the Site.

The Forder Valley and Bircham streams are Ordinary Watercourses upstream of the Blunts Lane/Plymbridge Road crossing, under the management of PCC as the Lead Local Flood Authority (LLFA). Downstream of Plymbridge Road the Forder Valley Stream is Main River, under the control of the EA.

The Forder and Bircham catchments are relatively flashy, i.e. flows and water levels respond quickly to rainfall events, due to runoff from the existing surrounding impermeable area and the steep topography.

The site is located predominantly in Flood Zone 1 and partially in Flood Zone 3, as shown on the Flood Map in Figure 2-1 (refer to Figure 1-1 for flood risk map in relation to the proposed development). Zone 3 comprises land that has been assessed as having greater than a 1% (1 in 100 year) probability of fluvial flooding. Zone 1 is defined as having a less than 0.1% (or 1 in 1000 year) probability of flooding each year.

The most recent modelling provided by the Environment Agency[6], shown in Figure 2-2 indicates that there is currently a medium to high risk of flooding in locations adjacent to the streams. The rest of the site is in very low risk areas.

[6] Environment Agency (2013) '*Long term flood risk information'* https://flood-warning-information.service.gov.uk/long-term-flood-risk/map - Accessed September 2019

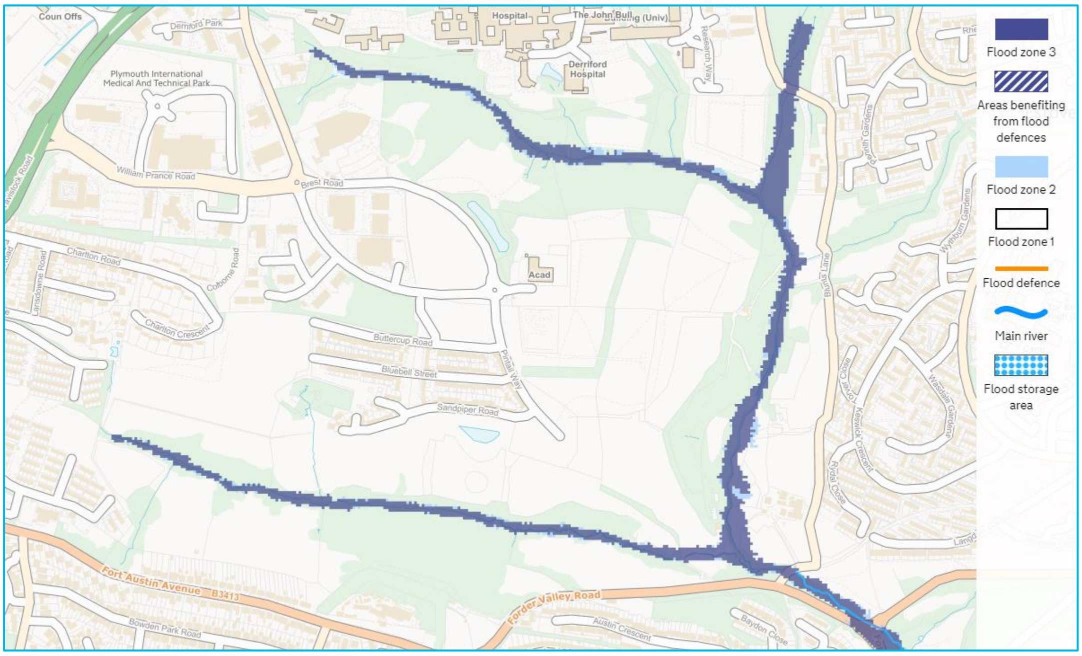

Figure 2-1: Environment Agency Fluvial Flood Zone Map for Planning

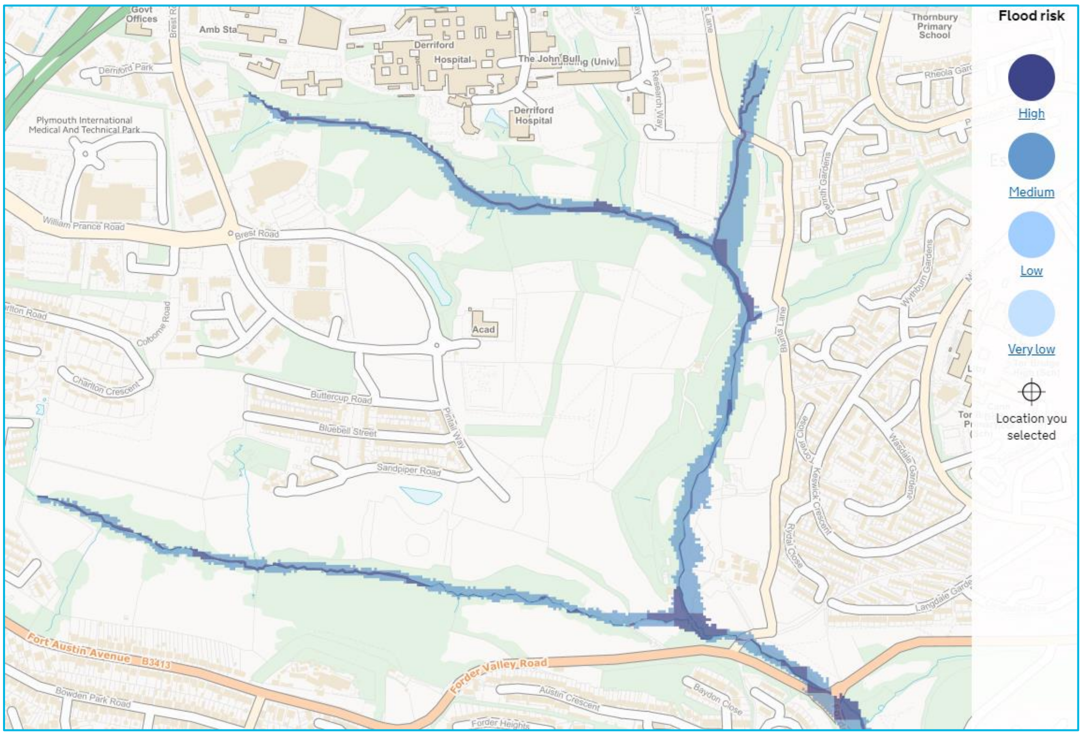

Figure 2-2: Environment Agency Extent of Flooding Map

2.3 Flooding from Groundwater

A WSP Flood Risk Assessment[8] for the link road was produced in February 2018 and contains a summary from a review of the Seaton Neighbourhood development FRA conducted in May 2012.

[8] WSP (2018) *Forder Valley Link Road Flood Risk Assessment*. https://planning.plymouth.gov.uk/online-applications/ - Accessed September 2019

"The records showed layers of weathered rock (clayey gravel) overlying a mudstone bedrock. The near surface soils were observed to have relatively high clay content.

During the investigation works referenced in the Seaton Neighbourhood development FRA, two falling head permeability tests were undertaken within each of the drilled boreholes. These tests were undertaken within the mudstone deposits at depths ranging from 1.5m below ground level (bgl) to 12.4m bgl. The underlying weathered rock and intact bedrock were recorded as having permeability ranging from 1.1 x 10-4 m/s to 9.6 x 10-7 m/s, with the majority of the tests falling within the 1 x 10-6 m/s range. No tests were undertaken within the near surface gravelly clays of the weathered rock or surface soils.

During the design of the Proposed Scheme, the appointed drainage design engineers, AECOM, conducted additional infiltration tests at the location of the proposed combined infiltration/attenuation pond during August 2017. The lowest recorded infiltration rate for this area was 2.15 x 10-5 m/s."

It should be noted that changes in groundwater levels do occur for a number of reasons including effects and variations in drainage. Such fluctuations may only be recorded by the measurement of the groundwater level within a standpipe or piezometer installed within appropriate response zones."

These infiltration rates and the space available for attenuation were not sufficient to deal with all Link Road surface water runoff, but indicated that it might be sufficient for managing volumetric runoff, i.e. the volume of runoff discharged from site. Detailed investigations and design of the attenuation pond found that infiltration would not be feasible and therefore an approach of controlled discharge to the watercourse via pipe outfall was adopted.

Regarding groundwater flood risk, geotechnical investigations in 2007 for the Seaton development identified that there was generally a low probability of significant groundwater emergence within the catchment of the streams in the Site and therefore there is a low groundwater flood risk.

2.4 Sewer Flooding

A review of SWW sewer mapping shows that there are a range of surface water and combined water sewers crossing and around the site.

A 600mm diameter surface water sewer discharges runoff from the Crownhill and Tavistock Road area to the west into the head of the Forder Valley Stream. This may also be a culverted section of the original head of the stream. Tavistock Road is at or near the watershed of the catchment with areas to the west draining through West Park to the Tamar.

A 225mm combined sewer runs parallel and to the north of the Forder Valley Stream, increasing to 375mm diameter where a 375mm foul sewer joins near the Bircham Stream. The foul sewer is 225mm diameter in the north west corner of the site and increases in diameter where it excepts connections from the surrounding development (Derriford Hospital, Business Park and residential areas).

No foul/combined sewer flooding events have been recorded in the area, and no Combined Sewer Overflows (CSO's) were located in review of the mapping within the site. There is a CSO outfall to the Forder Valley Stream downstream of the Wilburt Road crossing. It is expected that surface water sewers serving the existing, surrounding development and highway areas would be likely to flood in extreme storms (i.e. anything over the 3.3% AEP event) with flood flows travelling overland and into the watercourses.

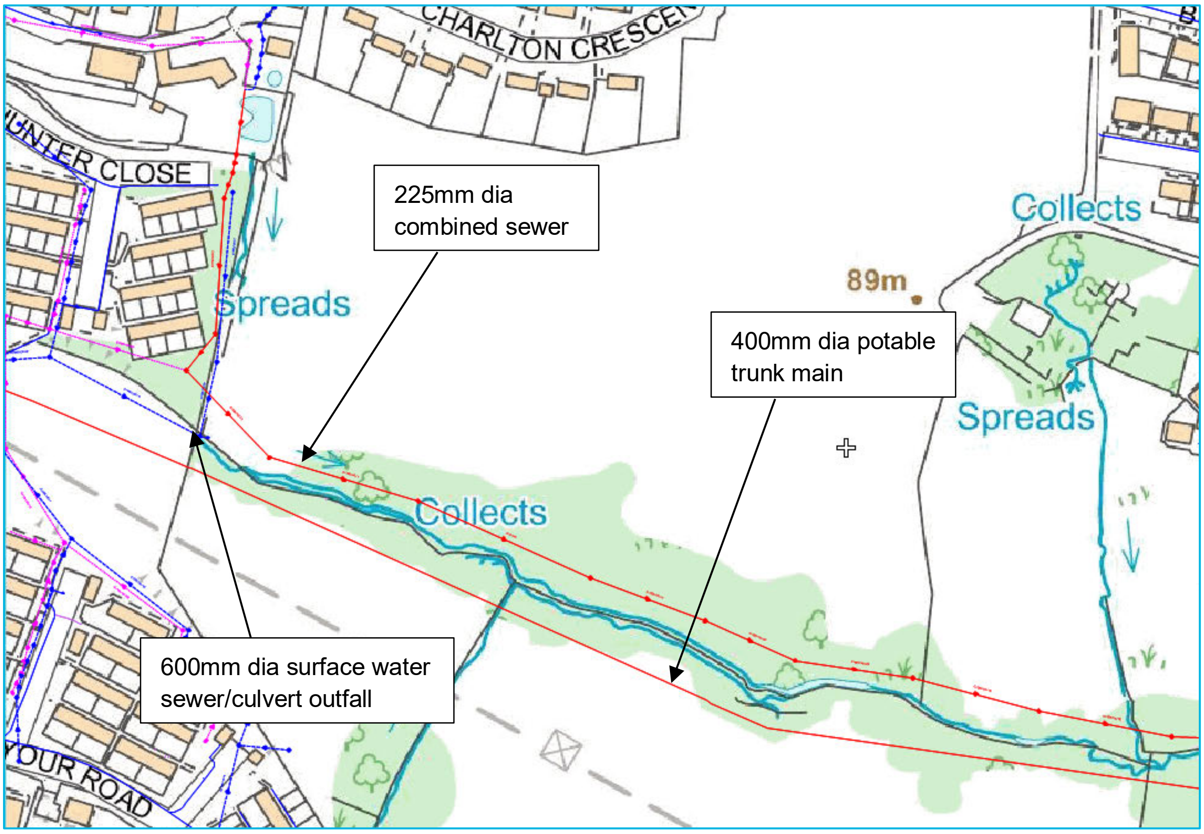

Figure 2-3: Sewers at Head of Forder Valley Stream

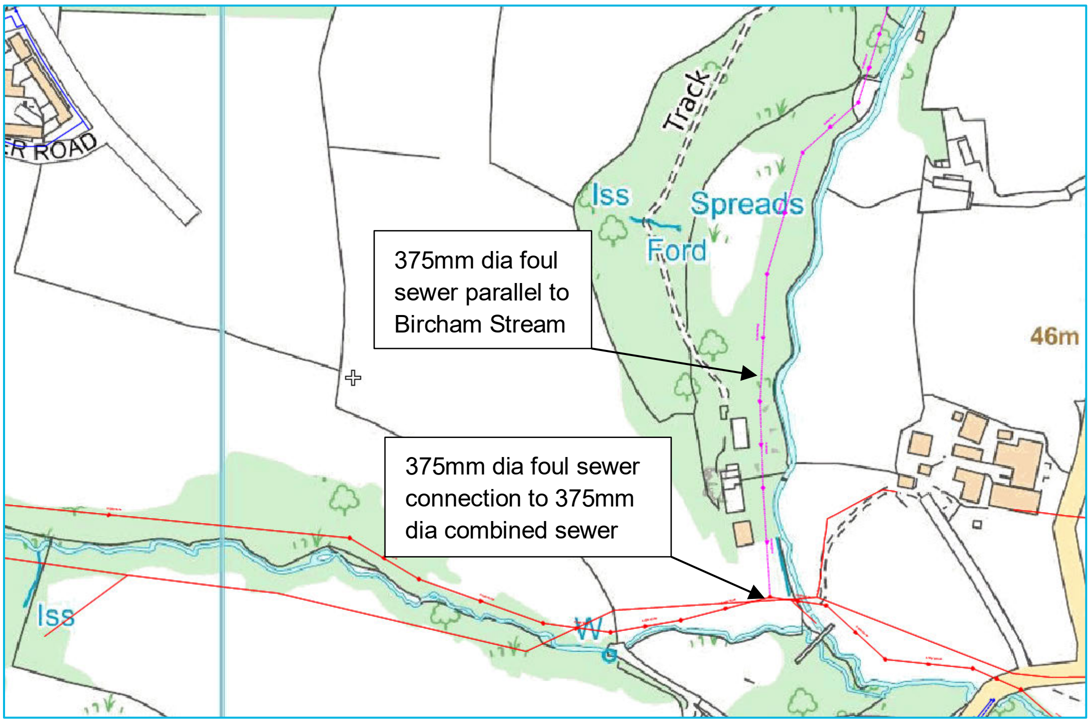

Figure 2-4: Sewers at Forder Valley and Bircham Confluence

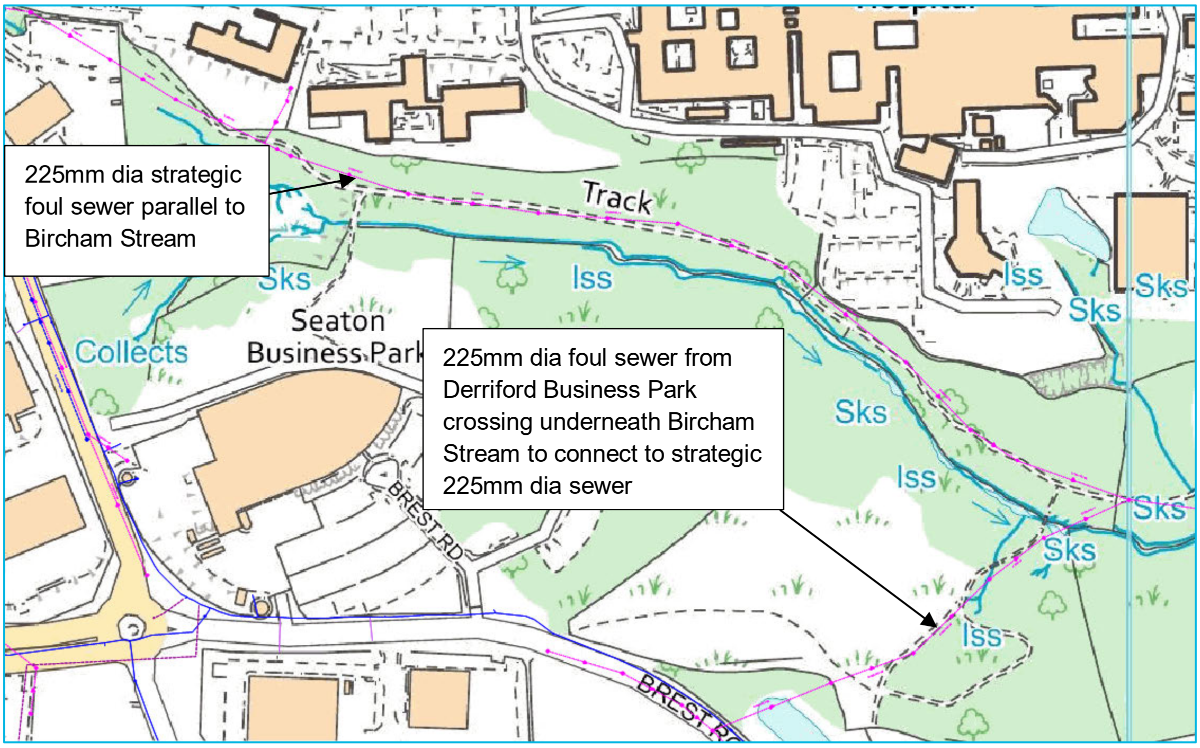

Figure 2-5: Sewers at Head of Bircham Stream

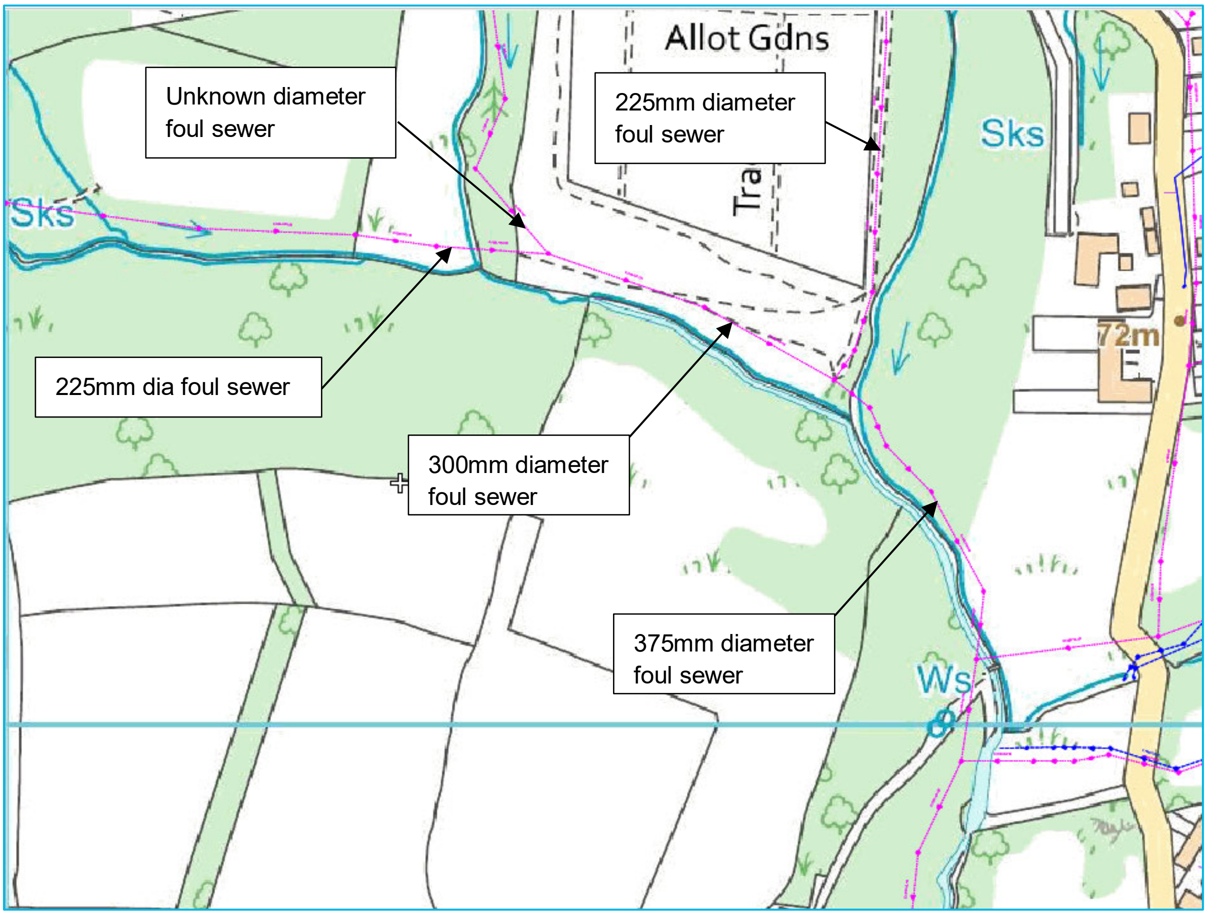

Figure 2-6: Sewers near North Eastern Reach of Bircham Stream

2.5 Surface Water Runoff and Drainage

Historic surface water sewer systems have often been designed to standards as low as 1 in 2 yrs. Therefore, high intensity rainfall in developed areas cannot drain to the sewers and flows overland following the topography, often following kerb lines. This is known as overland flow or pluvial flooding.

The site is surrounded by developed areas with surface water sewers issuing directly into the watercourse. As the catchment is steep, runoff from these areas is directed to the watercourses. The Environment Agency Surface Water flood map shown in Figure 2-7 shows medium to high risk of flooding in the developed areas. Runoff from the urbanised catchment and the steep gradient can lead to flashy flooding situations.

The flood map indicates that the high flood risk is associated with the watercourse main channels and medium flood risk associated with the overbank areas immediately alongside the main channel. The detailed view indicates that there is a high risk of flow at greater than 0.25m/s (relatively fast) within the channel and a medium risk of flow less than 0.3m deep, but at greater than 0.25m/s.

Therefore, the flood risk from pluvial sources for the majority of the site and the cycle routes is low, with medium flood risk immediately alongside the watercourse main channels.

Figure 2-7: Environment Agency Surface Water Flood Map

2.6 Flooding from Reservoirs

The Environment Agency Flood map, shown in Figure 4, indicates that the site has a very low risk of flooding from reservoirs, and will not be discussed further in this report.

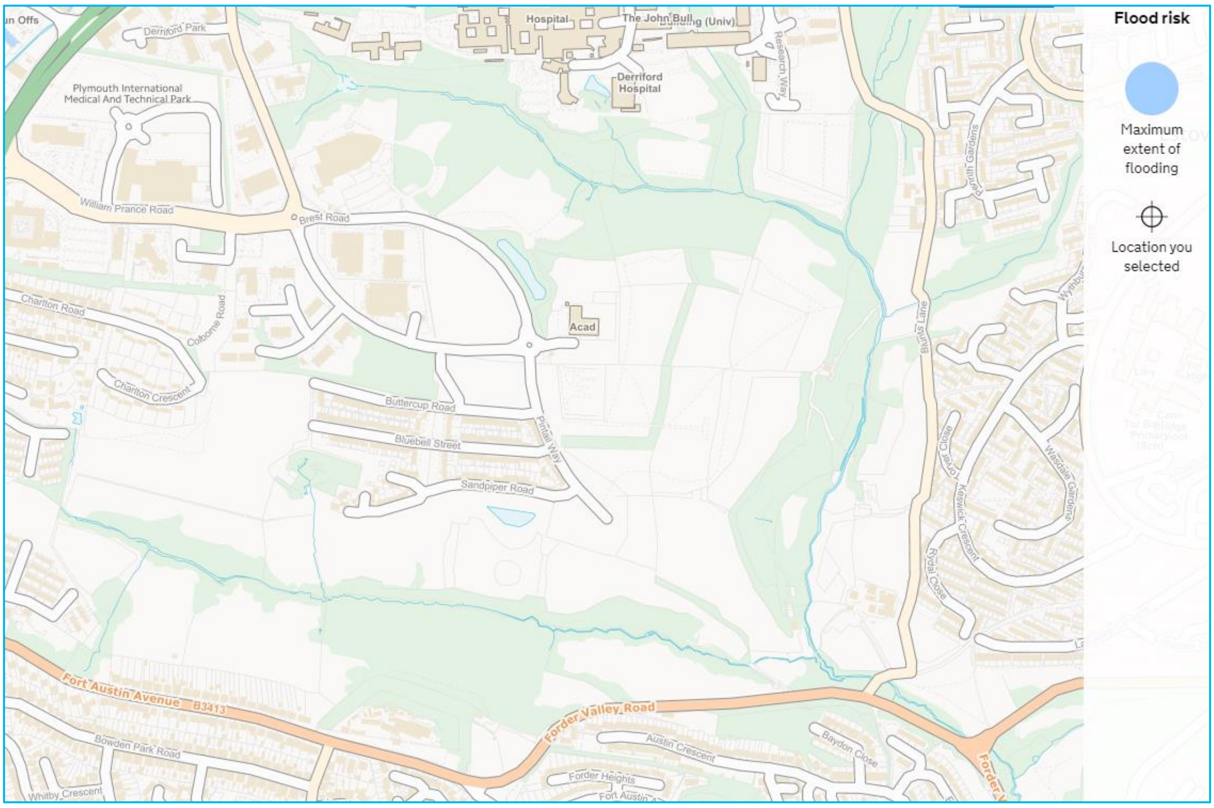

Figure 2-8: Environment Agency Reservoir Flood Map

2.7 Climate Change

The “Flood risk Assessments: Climate Change Allowances Guidance” published in February 2016 by the EA indicates that climate change is currently expected to result in increased peak rainfall and rising sea levels. Table 3 shows anticipated changes in extreme rainfall intensity in small and urban catchments within England. One hundred years is an appropriate design life for residential developments which corresponds to the year 2115 in the Table below. PCC have requested that infrastructure is designed to manage rainfall runoff and watercourse flows up to the 1% AEP plus 40% Climate Change event.

Table 3. Peak Rainfall Intensity Allowance in Small and Urban Catchments

Applies across all of England	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 2115)
Upper End	10%	20%	40%
Central	5%	10%	20%

Source: Environment Agency Website

2.8 Summary of Current Flood Risk

The existing flood risk from all sources to the site has been summarised in Table 4.

Table 4. Summary of Existing Flood Risk to the Site

Type of Flooding	Sources of Flooding	Existing Flood Risk
Fluvial	Bircham Stream Forder Stream	Medium
Groundwater	Underlying geology and groundwater levels	Low
Sewers	Foul Water Sewers	Low
Surface water	Runoff from surrounding developed land	Medium
Reservoir	None	Very Low

3. Post-Development Flood Risk

3.1 Proposed Development

The key features of the proposed Community Parks development are:

- Designated 3m and 2m pedestrian and cycle paths
- Bridges/crossings for the paths which cross streams and tributaries
- Landscaping
- Associated earthworks and engineering features for the above
  - Gabion retaining edges
  - Access points
  - Lighting ducting
  - Fencing
  - Pedestrian amenities and furniture

The proposed stream crossings have been given the designations in Table 5, for reference. There will also be culvert crossings of minor tributaries which have been indicated on the Drainage Strategy plan where possible.

Table 5. Stream Crossing References and Locations

Stream Crossing Ref.	Proposed Crossing Type	Location Description
Bircham		
1A	Culvert	Crossing of tributary in the north eastern part of the site. Alternate route available via 1B and 1C.
1B	Bridge	Immediately upstream of tributary, north eastern part of site.
1C	Bridge	Downstream of north eastern tributary.
1D	Bridge	Upstream of new Link Road bridge. To replace footbridge indicated in Figure 1-4.
1E	Bridge	Immediately upstream of existing ford at Forder/Bircham confluence and culvert.
Forder Valley		
2A	Bridge	Main route crossing near head of valley.
2B	Bridge	Minor route crossing approximately halfway along reach.
2C	Bridge	Minor route crossing just upstream of confluence.

The development proposals have been discussed with PCC as the stream crossings affect the Ordinary Watercourse reaches of the streams upstream of the EA Main River reaches.

3.2 Fluvial/Tidal Flood Risk

The Link Road FRA (WSP 2018) mentions that the Link Road culvert and channel works to both streams will have improved conveyance through the Community Park area and will reduce existing flood risk to the Site without affecting downstream flood risk. As such there is a negligible difference between the pre and post development scenarios in terms of flow rate and that velocities are generally decreased.

The earthworks and realignments of the Bircham Stream to accommodate the proposed Link Road bridge abutments/piers, along with the larger culvert to the Forder Valley Stream was demonstrated to cause a local reduction in flood levels.

3.3 Proposed Crossings

For the purposes of establishing parameters for water levels for setting the soffit height of proposed bridges, where possible the results from the WSP hydraulic model were used. Where this was not available, levels were estimated by the flood extents from EA mapping overlaid on the topographic survey and inspected. A Manning's calculation was then used to check these assumptions.

Crossings 1A, 1B and 1C

Crossing 1A is to be in the form of a culvert, nominally 900mm diameter, to the minor tributary – the exact size of the culvert will be confirmed at the detailed design stage, including a Trash Screen assessment to take into account unauthorised access risks as well as blockage and maintenance risks.

Flood mapping indicates the area to be in the flood plain for extreme events. An alternative route in these conditions would then be available via Bridges 1B and 1C. This arrangement would then limit the requirement for embankments constructed within the floodplain to take the cycleway up to bridge deck level. An example of this arrangement is given in Appendix C.

Crossing 1B is an existing bridge that would be replaced with a bridge of the same span and at the same soffit level, but with a wider deck to accommodate the wider track. Crossing 1C will follow the principles of bridges 1D and 1E, as discussed, below.

Crossings 1D and 1E

Typical bridge section arrangements have been indicated on drawings FVLR-ACM-05-XX-DR-DR-00005 and 00006 in Appendix C. A 5m single-span bridge arrangement has been indicated, which would be in the form of a proprietary steel bridge solution. The bridge soffit will be set 600mm above the 1% AEP plus 40% Climate Change water level to allow freeboard (as discussed with PCC Strategic Planning and Infrastructure) e.g. for reducing the likelihood of blockage from debris transported by the stream. The estimated flow from the hydraulic modelling report (WSP, 2018 - Appendix D) is 8.12m^3/s. The hydraulic modelling was approved by the EA as part of the July 2019 Link Road planning application.

A Manning's calc for the 5m wide bridge opening with a watercourse bed gradient of 1:20 gives a capacity of 45m^3/s (using a water level of 25.4mAOD, taken from the 2017 WSP Hydraulic Model results). Therefore, it is proposed to install partially buried 600mm pipes in the embankments either side of the bridge crossing to provide flood relief and floodplain connectivity in an out-of-bank event as the main flow would be expected to remain within the central channel.

Bridge 1E is immediately upstream of the proposed Link Road embankment/Plymbridge Road culvert which controls the flow in this area. The culvert has a cross-sectional area of 6.5m^2 (2.7m wide x 2.4m high). The proposed bridge structure will have a cross-sectional flow area of approximately 7.7m^2 at a water level of 25.4mAOD.

Other Crossings

New bridges along the Forder Stream will follow the principles of bridges 1D and 1E, as discussed above. Crossings of minor tributaries as identified on the plans will be in the form of simple tracks and earthworks over culverts.

Residual Risks

Where the tracks are located within and cross the floodplain at and around crossing locations, there will be a residual risk of flooding of the tracks in extreme events, particularly where the tracks will be set at existing ground levels to minimise impact on the catchment.

Additional bridges and culverts will help hold back some sediment. The streams catchments are flashy and sediment is highly mobile – holding back some sediment should help improve water quality in-line with the Water Framework Directive (WFD).

3.4 Flooding from Groundwater

The cycleways are to follow the routes of existing tracks and the historic tram way. Therefore, it is assessed that the proposed development would not increase the existing risk of groundwater flooding at the site or be affected by existing groundwater flood risk. Land drainage/surface water interception features are to be included as described in 3.6, below.

3.5 Sewer Flooding

The position of proposed bridge abutments will need to appreciate the routes of the existing foul and combined sewers, particularly near Bridge 1E, to avoid the necessity for sewer diversions. These would need to be discussed and agreed with SWW.

There is no requirement for foul drainage and no foul load created by the development. Therefore, the overall flood risk from sewers is considered to be low.

3.6 Surface Water Runoff & Drainage

From the FRA developed by WSP, with regards to the Link Road development, *" Overland surface water flows from the north of the proposed scheme will be managed by cut off drains and ditches that will convey the water back to Bircham Stream and Forder Stream, as per the current situation."*

Surface water runoff from the proposed Seaton Neighbourhood and Forder Valley Link Road developments is to be managed on-site with discharge from attenuation systems restricted to the 10% AEP (1 in 10yr) greenfield runoff rate for storms up to and including the 1% AEP (1 in 100yr) plus 40% Climate Change event. This is in-line with the PCC guidance for sustainable development within the Plymouth Critical Drainage area. As the site is steep and responsive to rainfall events, this restriction should mimic the release of the volume of runoff from the greenfield catchment, thereby mitigating the potential increase in surface water flood risk.

The Seaton Neighbourhood and Link Road schemes each have an individual attenuation pond discharging into the Forder Valley Stream upstream and downstream of the Bircham Stream confluence, respectively. The respective discharge rates from the proposed attenuation features for the 1%AEP plus 40% Climate Change are 74.3l/s and 21l/s, giving a total peak discharge of 95.3l/s, which is negligible with respect to the total flow in the watercourses and reduces the peak flow to the watercourse for extreme events.

The cycle routes are to be constructed from a porous asphalt surface so as not to increase the impermeable area of the site. Bridge decks will intercept rainfall that would have fallen directly into the watercourse.

Surface water interception drains (shallow ditches and/or filter drains) will be required at topographical low points along the cycle routes, with pipes under the route to ensure that surface water from the natural catchment does not wash out the track construction material. These drainage features would also intercept high groundwater if this were encountered at certain times of the year, which could push up through (pump) the surfacing courses. Lateral restraints such as kerbs or bedded stones across the tracks, particularly on longitudinally steeper sections of track would also assist in retaining surface material in extreme rainfall events.

A typical cross-section detail is included in Appendix C that demonstrates the track construction. The porous surface is to be laid on a "Cellweb" system that provides runoff storage, mimicking the capacity of existing green areas (and providing a betterment to compacted/made ground areas, particularly along existing track routes where natural infiltration and ground water movement is impeded). Treated timber edging will provide restraint to surface material to prevent this from being washed-out over time and through scour from overland flows in extreme events. This construction type has been designed to protect the surfaces from overland and groundwater flows, as well as aid maintenance, for the lifetime of the development.

The Drainage Strategy Plan (FVLR-ACM-05-MZ-DR-DR-10019) in Appendix B illustrates the site arrangement and flood flow routes through the site.

Therefore, the risk from the development to the overland flow (pluvial flooding) is considered low.

3.7 Summary of Post-Development Flood Risk

The flood risk of the site resulting from the proposed development is summarised in Table 6.

Table 6: Summary of Flood Risk to the Proposed Development

Type of Flooding	Sources of Flooding	Flood Risk
Fluvial	Bircham Stream Forder Stream	Medium
Groundwater	Underlying geology and groundwater levels	Low
Sewers	Foul Water Sewers	Very Low
Surface water	Runoff from surrounding developed land	Medium
Reservoir	None	Very Low

By using porous construction for the new tracks and following existing tram routes etc. where possible, managing surface water overland flows and groundwater if encountered, with appropriate surfacing construction (including edge restraint) the development will not increase flood risk to the site and the surrounding area.

4. Sequential Test and Exception Test

4.1 Sequential Test

Paragraph 101 of the National Planning Policy Framework (NPPF 2012) refers to the sequential test and states:

"*The aim of the Sequential Test is to steer new development to areas with the lowest probability of flooding. Development should not be allocated or permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower probability of flooding. The Strategic Flood Risk Assessment will provide the basis for applying this test. A sequential approach should be used in areas known to be at risk from any form of flooding*."

4.2 Methodology

The methodology for the application of the sequential test is based on the Environment Agency guidance note "Demonstrating the flood risk Sequential Test for Planning Applications"[9].

4.3 Strategic Application & Development Vulnerability

The guidance recommends that: *The Sequential Test can be considered adequately demonstrated if both of the following criteria are met:*

- *The Sequential Test has already been carried out for the site (for the same development type) at the strategic level (Local Plan); and*
- *The development vulnerability is appropriate to the Flood Zone (see table 3 of technical guidance to the NPPF).*

The site, for its proposed development type, has been allocated as part of PCC's development plans for the Seaton Neighbourhood, and therefore a sequential test is not required.

4.4 Exception Test

According to the Technical Guidance of the NPPF[12], the proposed open space and essential infrastructure development has a vulnerability classification of 'Water-compatible'. The proposed development is predominantly located in Flood Zone 1 with Flood Zone 2 and Flood Zone 3b where the proposed tracks cross the streams, typically the 3m wide primary routes per Figure 1-1. Parameters for the design of cycle route infrastructure where it crosses FZ 2 and 3 have been set to have minimal impact on the floodplain and flood water levels.

4.5 Conclusion

The development can be shown to pass both the Sequential and Exception tests by being part of PCC's local development plans and applying appropriate land uses to the relevant Flood Zones within the site.

[9] Environment Agency: '*Demonstrating the flood risk Sequential Test for Planning Applications'* http://webarchive.nationalarchives.gov.uk/20140328110923/http://www.environment-agency.gov.uk/static/documents/Sequential_test_process_4.pdf [Accessed 14/11/17]

[12] Communities & Local Government (2012) '*Technical Guidance to the National Planning Policy Framework'* Department for Communities and Local Government: London.

5. Mitigation Measures

This section of the report is included to demonstrate that the proposed development can meet the requirements of current policy. The NPPF advocates that 'inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk, but where development is necessary, making it safe without increasing flood risk elsewhere'.

5.1 Site Drainage

The proposed surfacing for the cycleways is porous asphalt so as not to increase the site impermeable area and avoid potential issues with surface materials being washed away in extreme rainfall events. Where porous gravel surfaces are to be used, say for secondary routes, intermediate channels and lateral restraints, such as kerbs laid across the track may be required to manage surface water on steep gradients and at low points (see section 3.6).

The tracks are to be used as cycle/footways only, i.e. there will be no vehicular traffic. Therefore, there will be a very low pollution risk from runoff from the surfaces.

5.2 Flood Resilience

Flood resistant construction in this case can be defined as designing infrastructure to be able to operate during flood conditions.

Bridge crossings are to be made flood resilient by setting the soffit of the bridge deck 600mm above the 1% AEP plus 40% Climate Change flood level (to mitigate against blockage from material and debris, such as fallen trees and branches, washed down from the upper catchment). This level will be set for each location based on assessment of topography, flood mapping and interpolation from existing hydraulic models. Culvert pipes set into the embankments will provide floodplain connectivity and allow out of bank flow beneath the cycle routes in case of blockage to the main channel.

PCC will require a Flood Defence Consent (FDC) application to be made prior to works commencing in or around the Ordinary Watercourses.

5.3 Flood Compensation

No flood compensation is expected to be required as the effect on the floodplain by the cycle route infrastructure will be negligible.

5.4 Construction Phase

The Plymouth Local Flood Risk Management Strategy requires that a Construction Environmental Management Plan (CEMP) is produced by or for the contractor to ensure that flooding, pollution and ecology, etc. is considered and managed during the construction phase.

6. Conclusions & Recommendations

The application of the sequential and exception test has concluded that the site is suitable given existing flood risk, requirement in local plans, location and amenity value for the local area.

By establishing the available data, the existing flood risk to the site from all sources has been assessed. Using the proposed layout of the site, the flood risk has been determined for the proposed development as well as the effect that the proposed development might have on flood risk elsewhere. Future climate change has been considered.

Mitigation will be implemented to reduce the flood risk to and from the proposed development.

The assessment can be summarised as follows:

- The indicative EA flood map indicates that the site is located in predominantly in Flood Zone 1 and partially within Flood Zone 2 and 3 for essential and water-compatible development.
- Other sources of flooding such as groundwater and sewers have been assessed and the risk attached has been considered to be low to medium currently and post-development; and
- Surface water can be managed using porous surface construction and appropriate land drainage/surface water interception techniques, as required.

The proposed development will not increase the risk of flooding at the site or within the surrounding areas.

The proposed development is in line with the policies as listed in Section 1.2. In accordance with the NPPF, the site is not at significant risk from flooding and will not increase flood risk elsewhere in the catchment.

It is considered that the recommended mitigation will be put in place and managed for the lifetime of the proposed development by PCC.

Appendix A Topographical Survey

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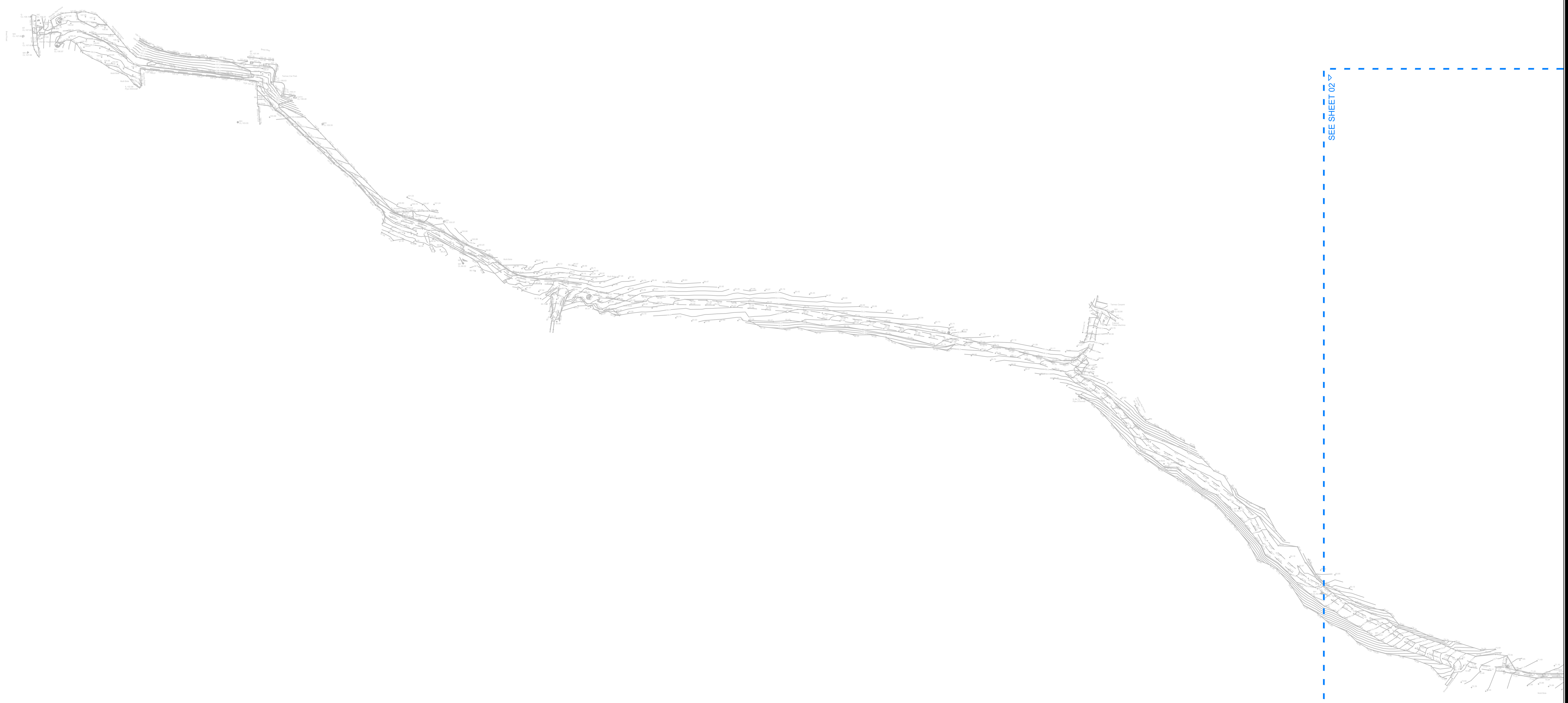

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CONSULTANT

AECOM
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Plumer House
Tailyour Road
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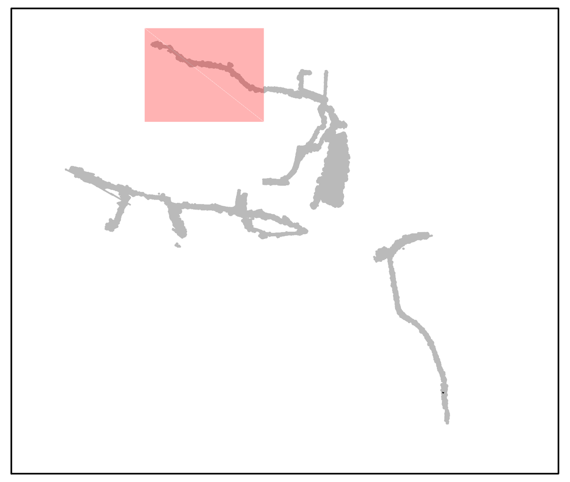

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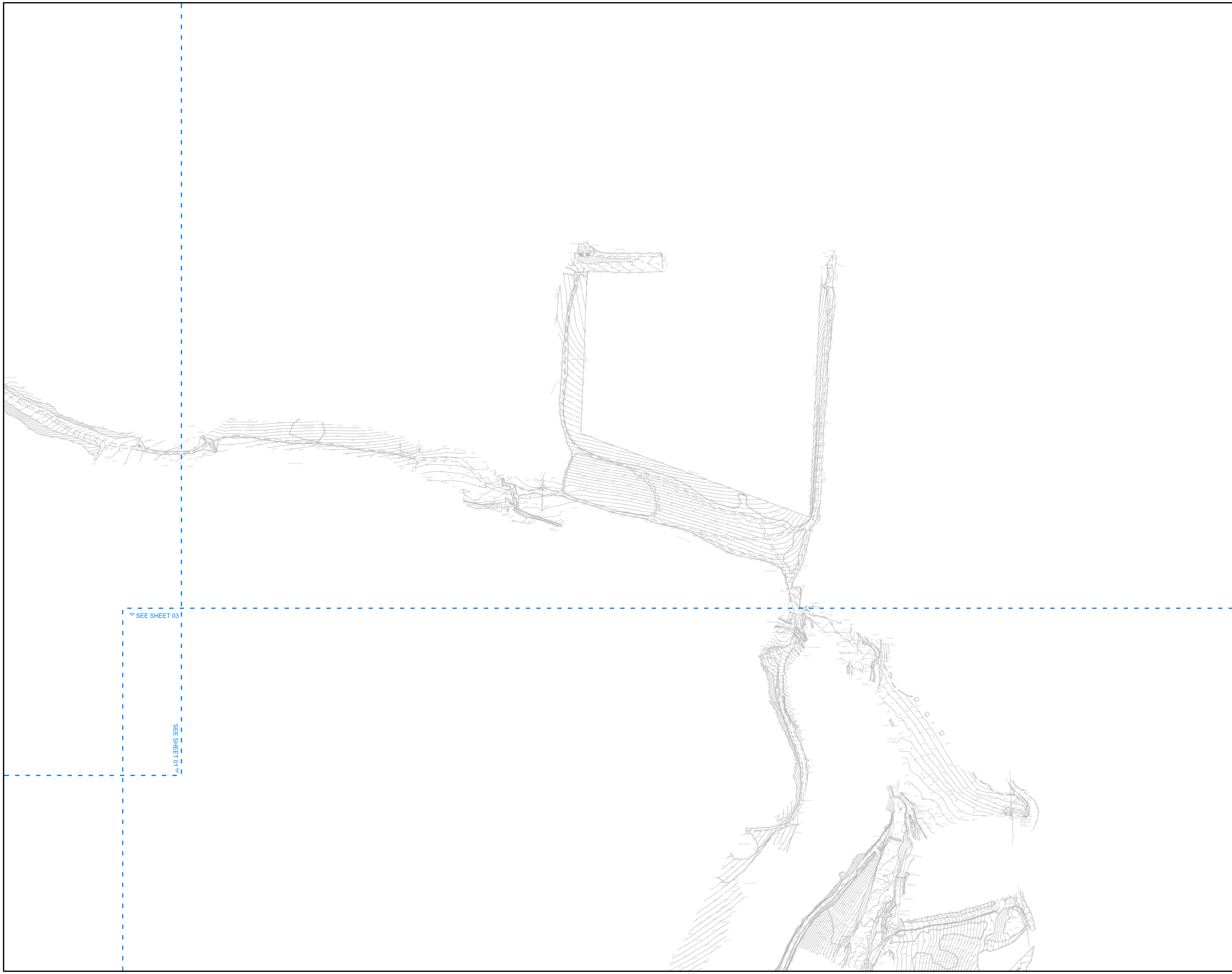

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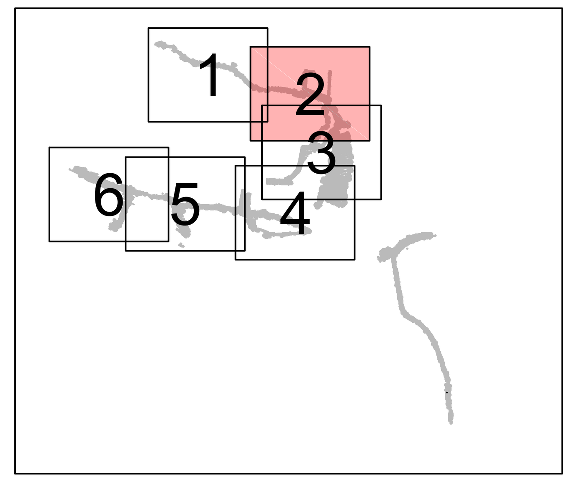

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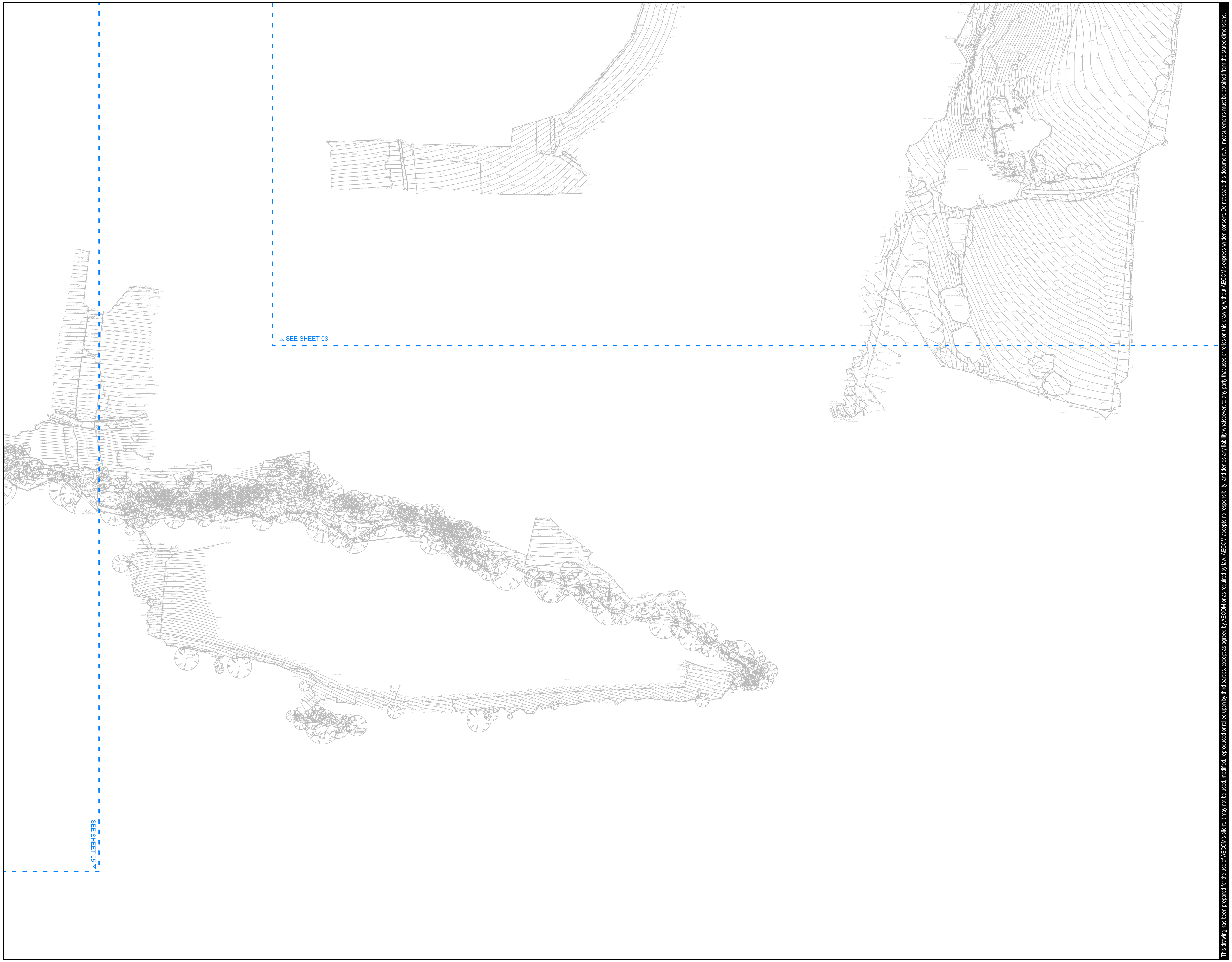

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Plumer House
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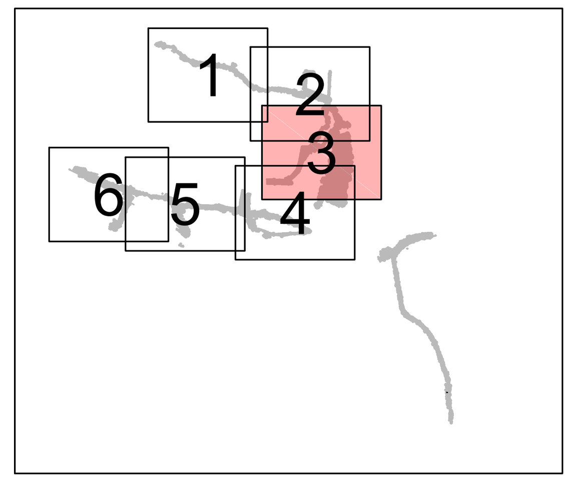

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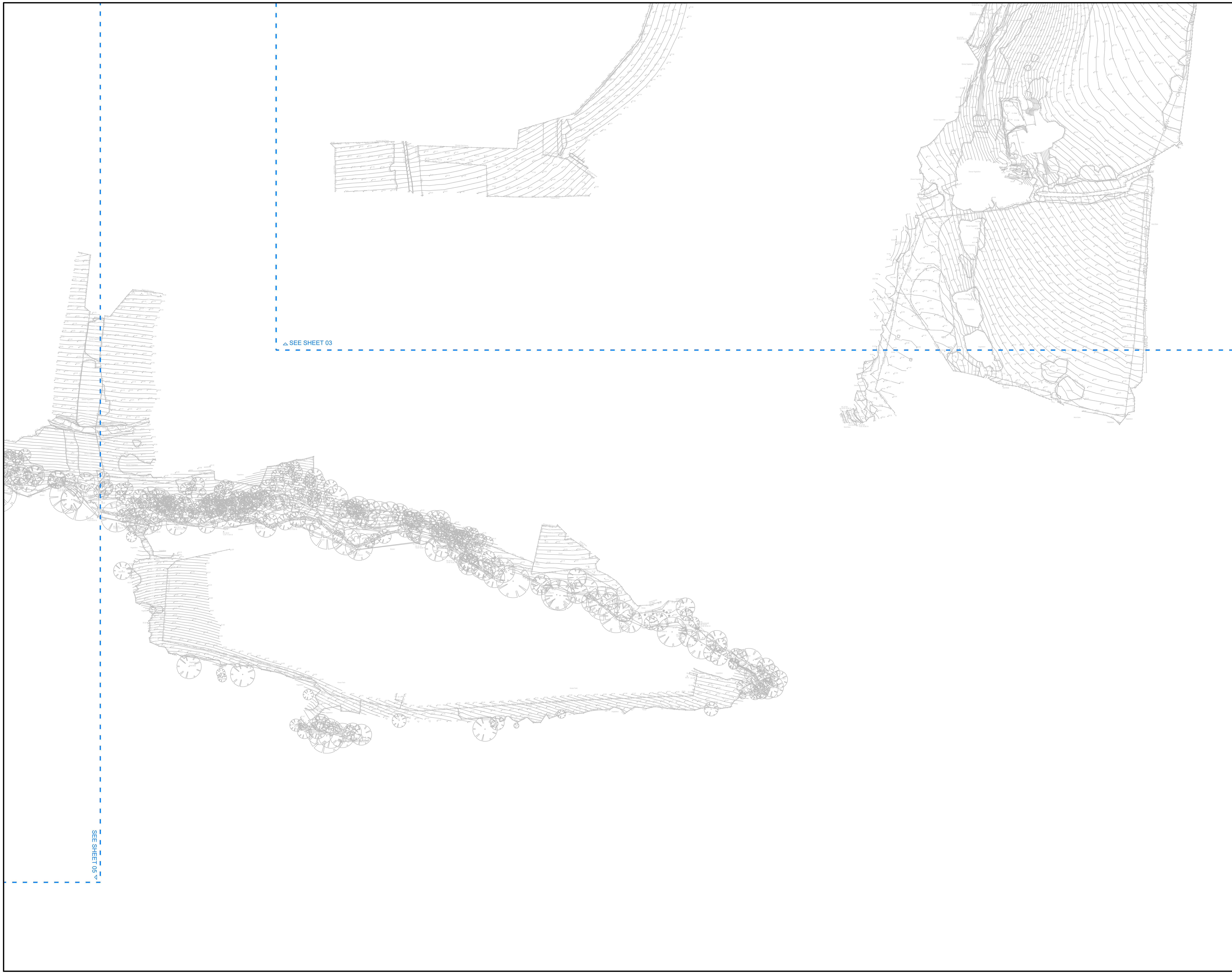

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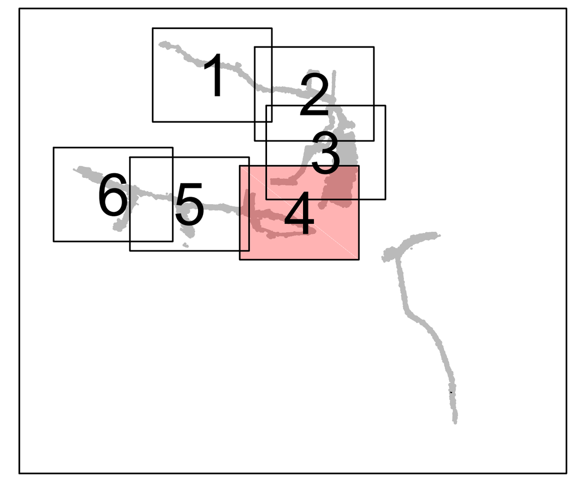

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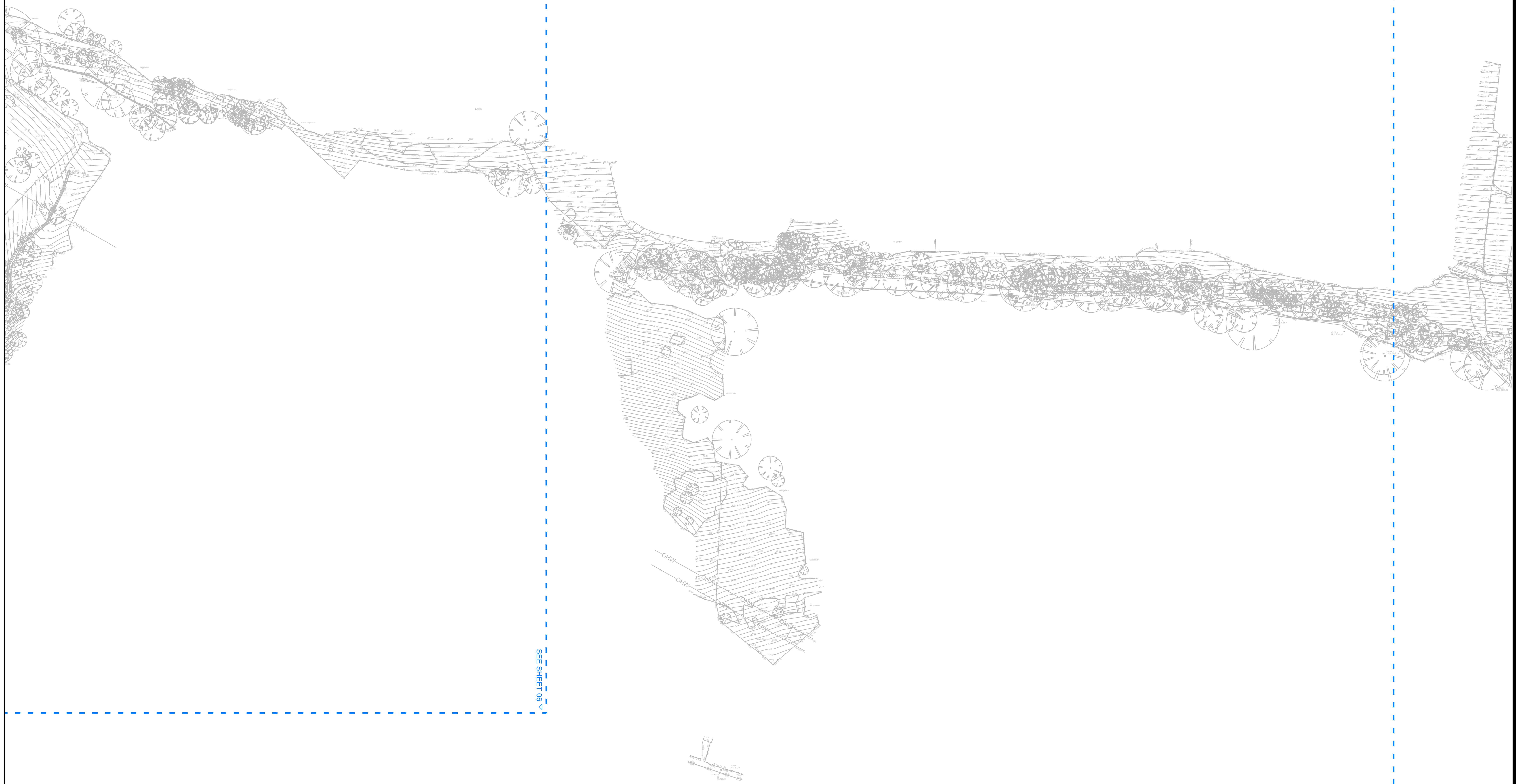

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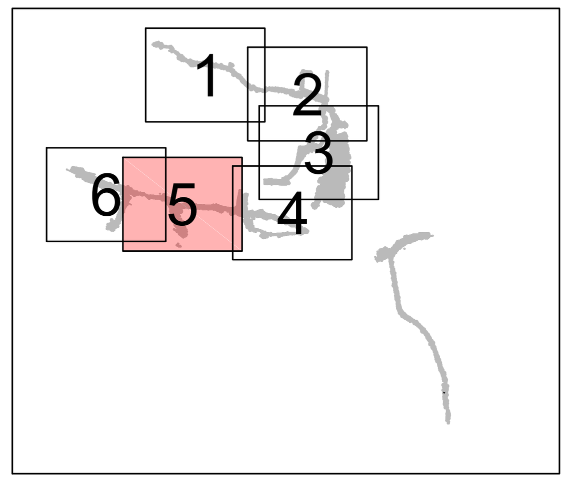

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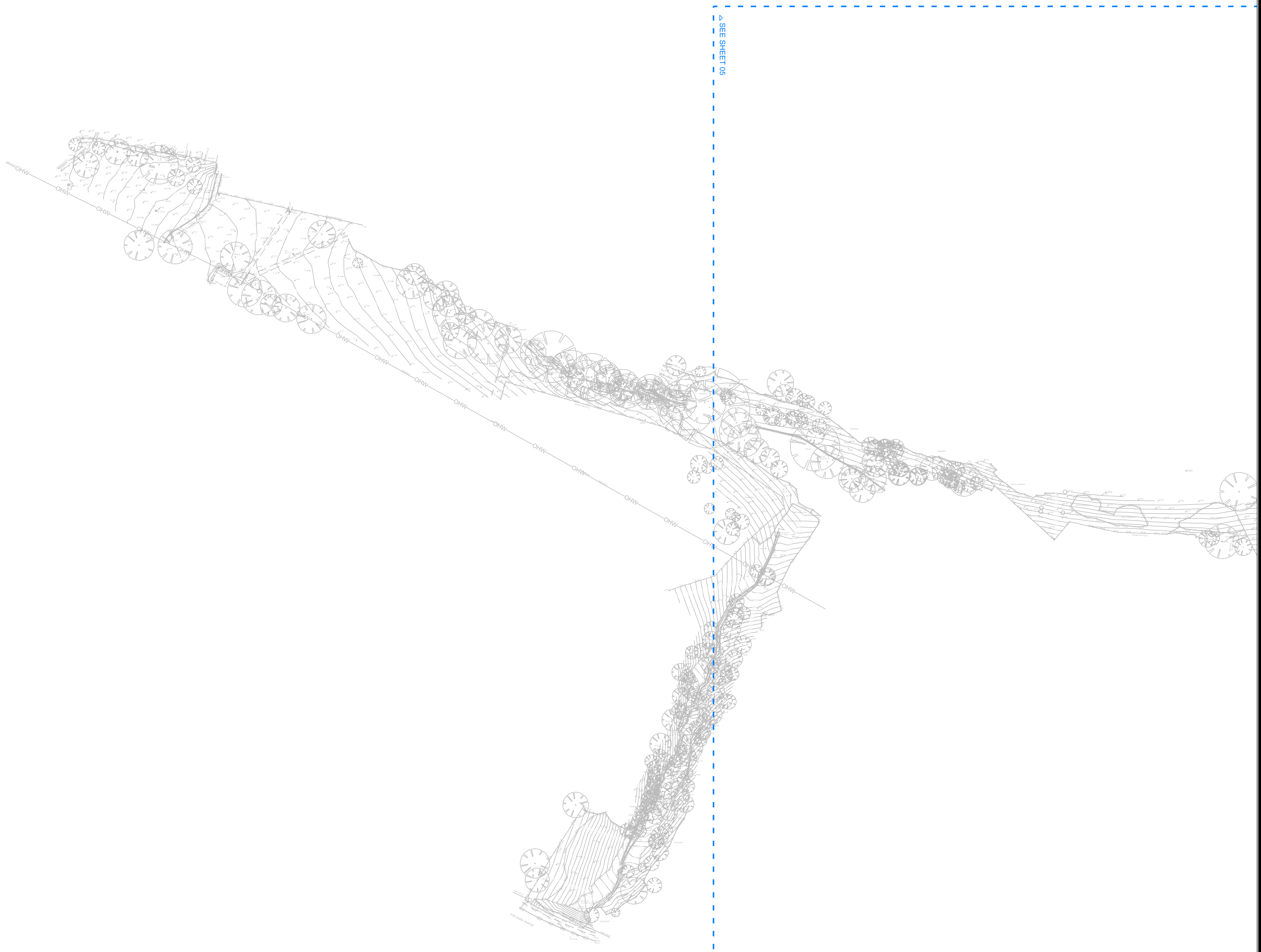

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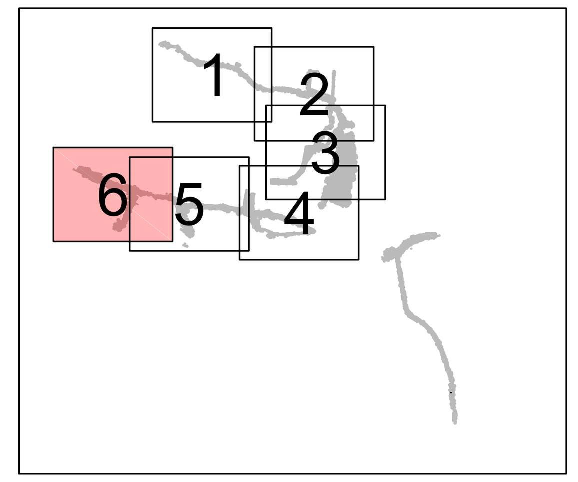

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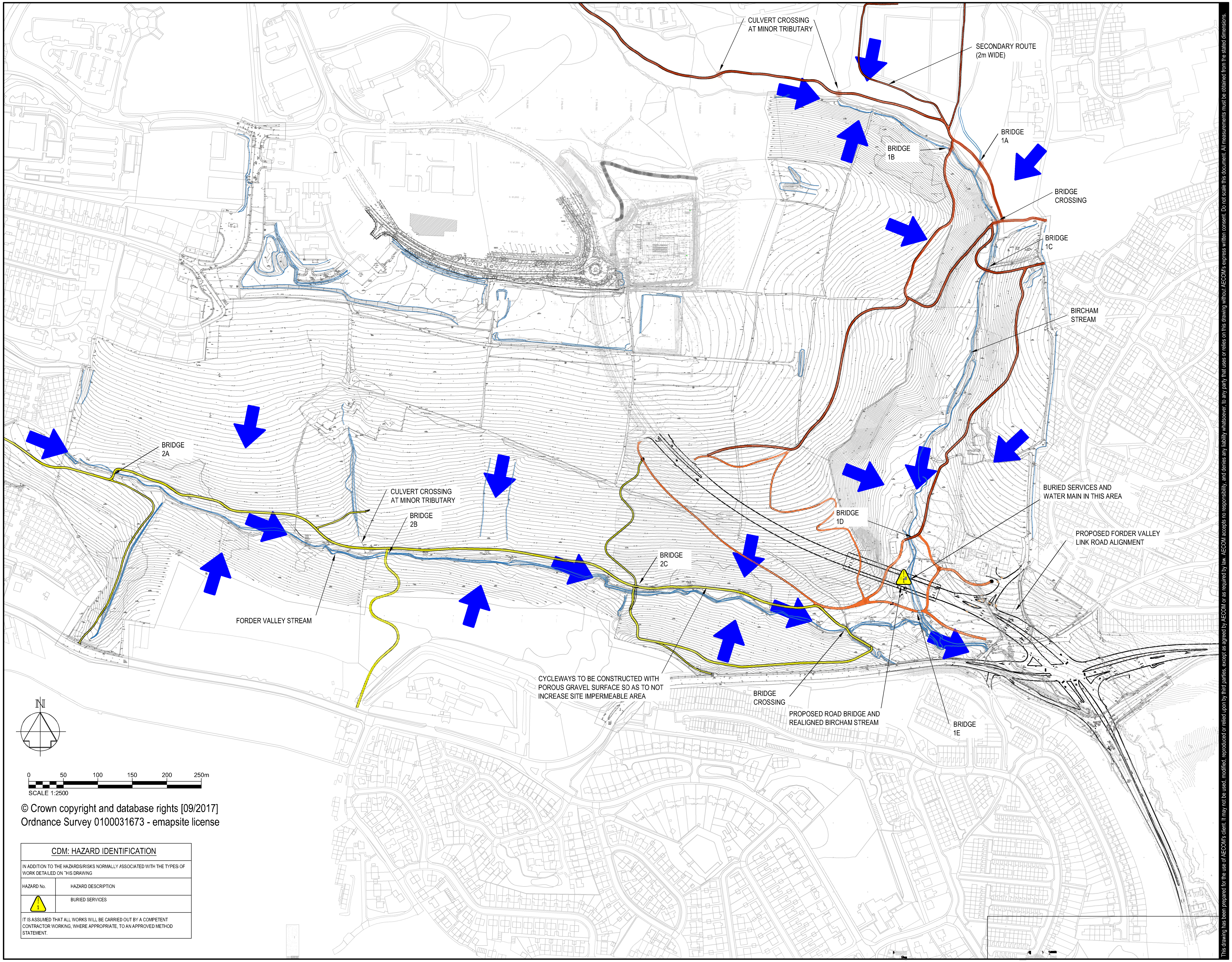
BVCP-ACM-26-S6-DR-HY-000001 P01.1

Appendix B Drainage Strategy Plan



CDM: HAZARD IDENTIFICATION

IN ADDITION TO THE HAZARDS/RISKS NORMALLY ASSOCIATED WITH THE TYPES OF WORK DETAILED ON THIS DRAWING

HAZARD No.	HAZARD DESCRIPTION
1	BURIED SERVICES

IT IS ASSUMED THAT ALL WORKS WILL BE CARRIED OUT BY A COMPETENT CONTRACTOR WORKING, WHERE APPROPRIATE, TO AN APPROVED METHOD STATEMENT.

AECOM

PROJECT

FORDER VALLEY
LINK ROAD

CLIENT

BALFOUR BEATTY

CONSULTANT

AECOM
3rd Floor, East Wing
Plumer House
Tailyour Road
01752 676700

GENERAL NOTES

1. DO NOT SCALE FROM THIS DRAWING.
2. ALL DIMENSIONS, CO-ORDINATES AND LEVELS ARE GIVEN IN METRES UNLESS SHOWN OTHERWISE.
3. CYCLEWAYS TO BE OF PERMEABLE GRAVEL CONSTRUCTION

DRAFT

DRAWING STATUS

INITIAL STATUS OR WIP

ISSUE/REVISION

I/R	DATE	DESCRIPTION
P01.1	04/10/19	First Issue

PROJECT NUMBER

60535194

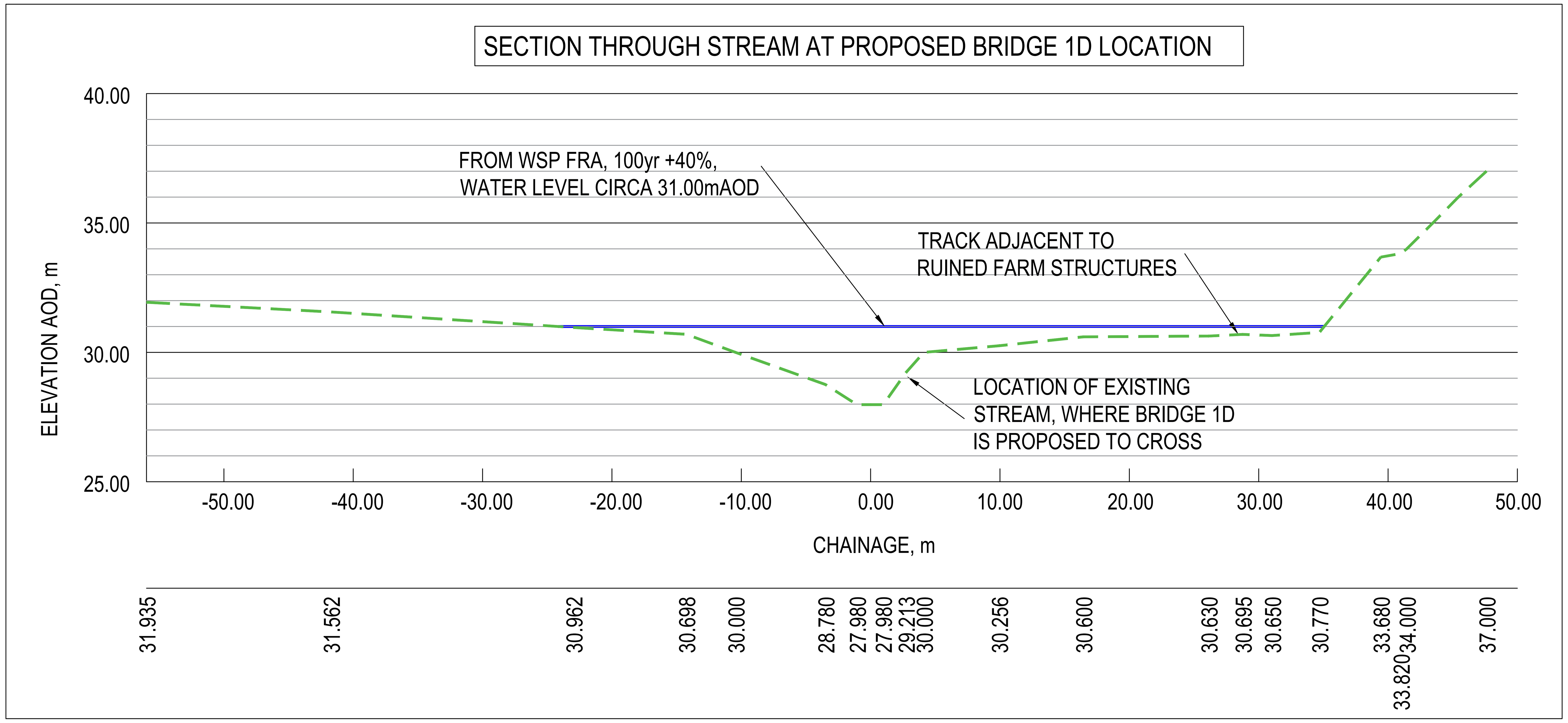
SHEET TITLE

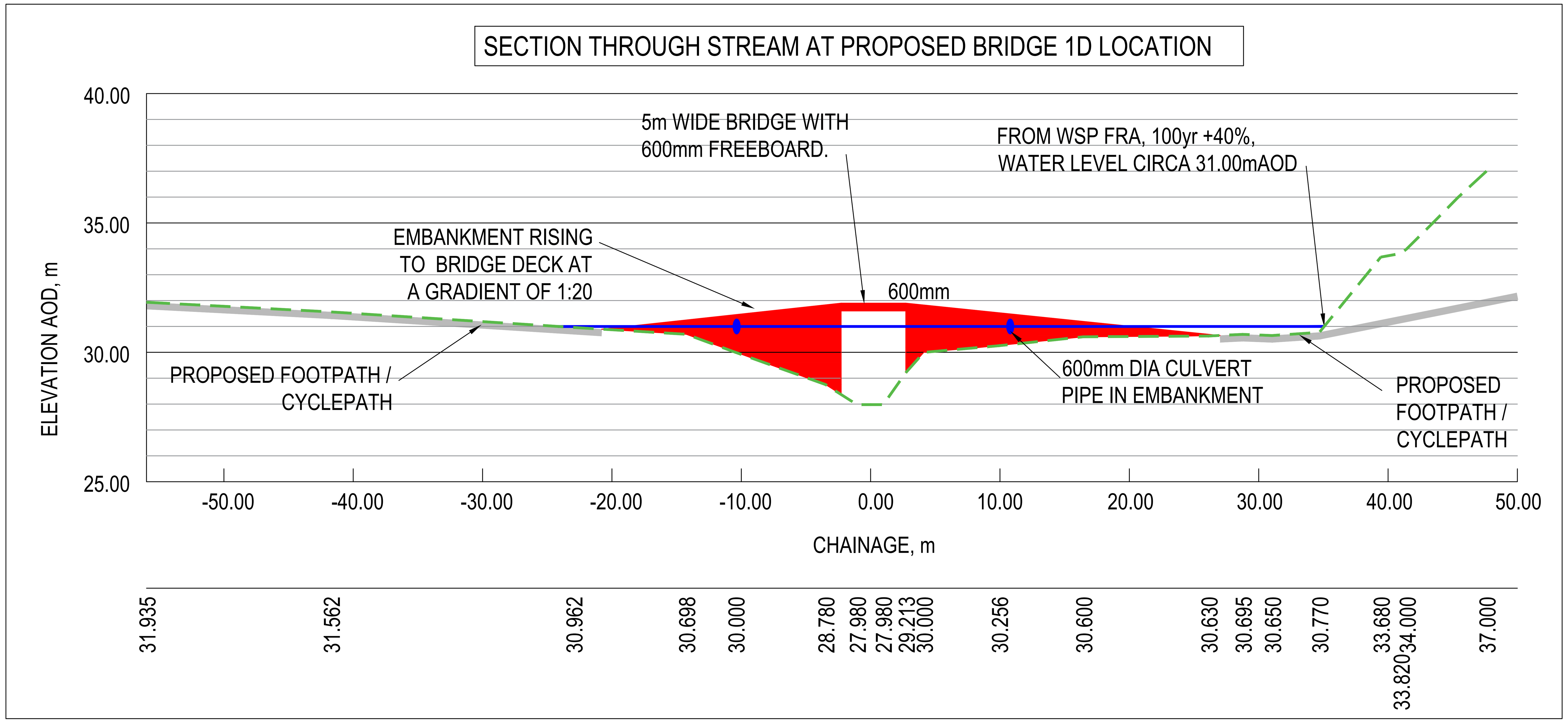
FORDER VALLEY
COMMUNITY PARK
CYCLEWAY ROUTE
DRAINAGE STRATEGY

SHEET NUMBER **REV.**

FVLR-ACM-05-MZ-DR-DR-10019 P01.1

Appendix C Typical Sections and Details





SCALE	V - 1:125
	H - 1:250

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PROJECT

FORDER VALLEY LINK ROAD

CLIENT

BALFOUR BEATTY

CONSULTANT

AECOM
3rd Floor, East Wing
Plumer House
Tailyour Road
01752 676700

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KEY PLAN

DRAWING STATUS

INITIAL STATUS OR WIP

ISSUE/REVISION

I/R	DATE	DESCRIPTION
P01.2	06/12/19	Cycle Route Added

PROJECT NUMBER

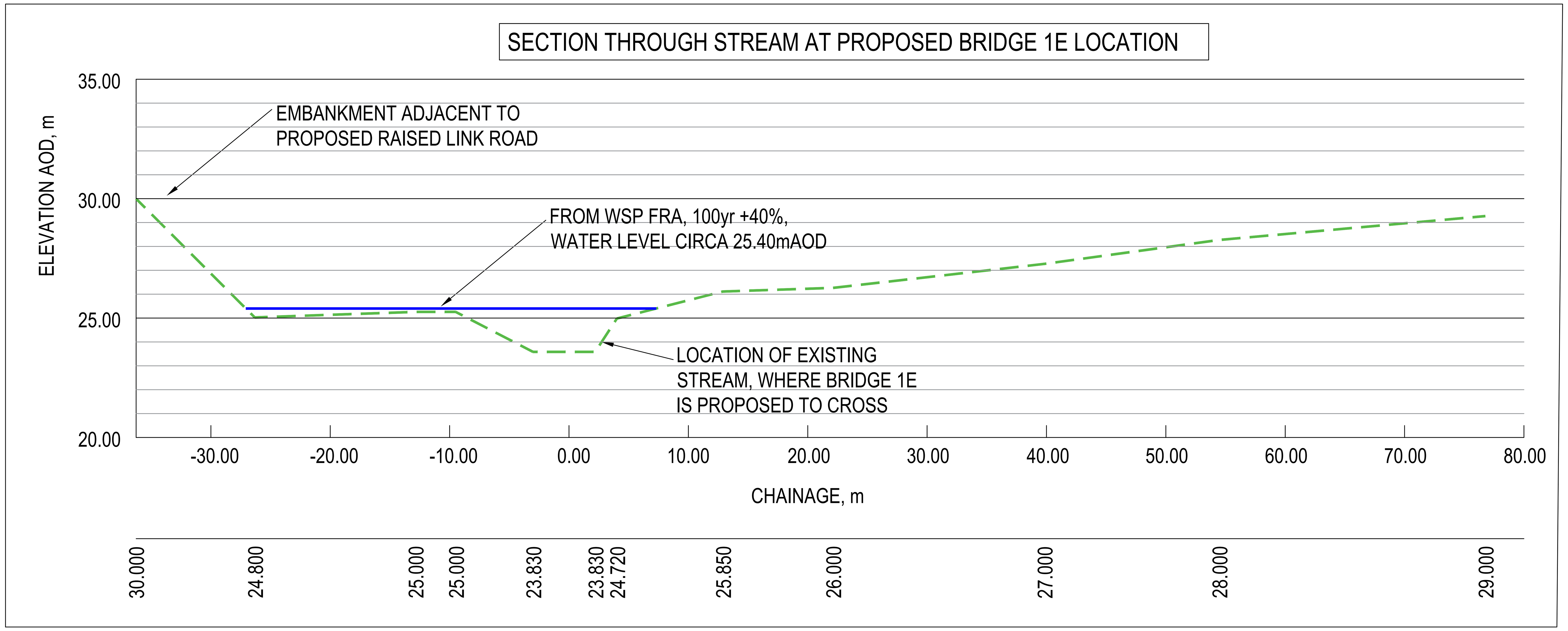
60535194

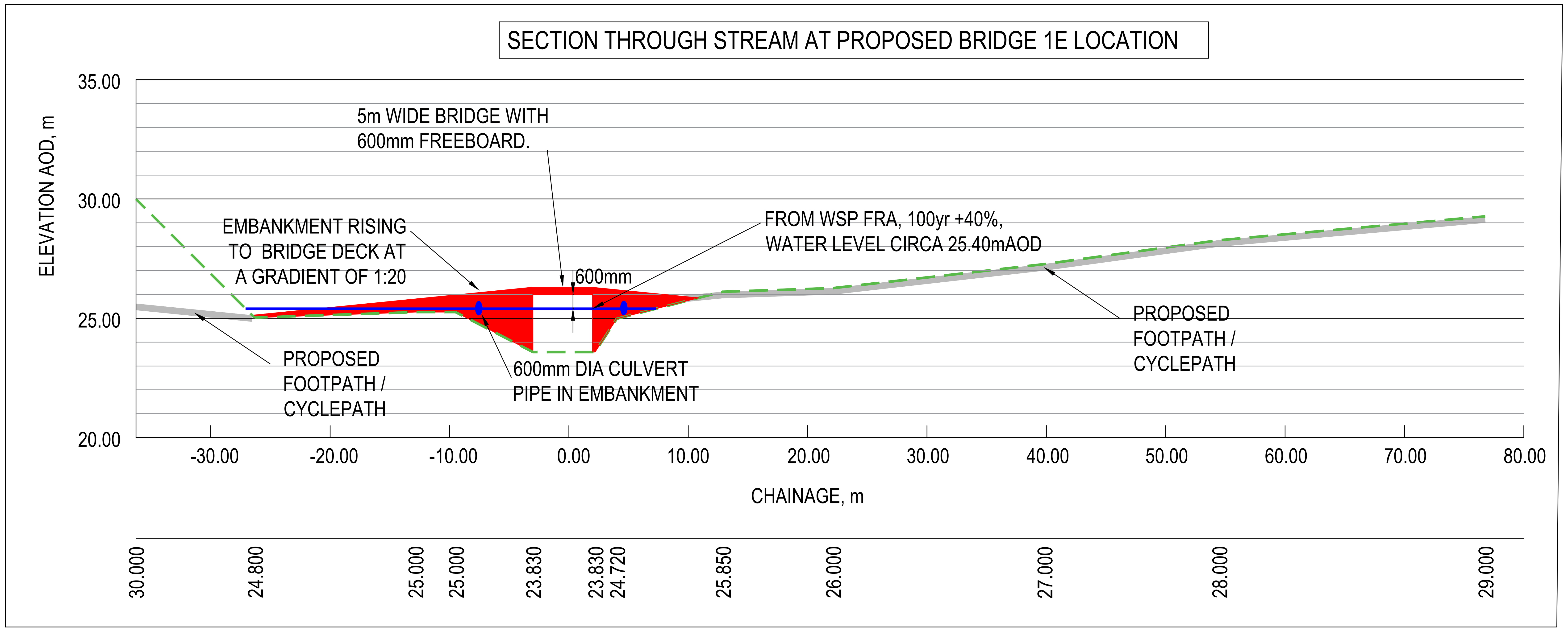
SHEET TITLE

FVLR
COMMUNITY PARKS
BRIDGE SECTIONS
BRIDGE 1D

SHEET NUMBER **REV.**

FVLR-ACM-05-XX-DR-DR-00005 P01.2





SCALE V - 1:125
H - 1:250

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FORDER VALLEY LINK ROAD

CLIENT

BALFOUR BEATTY

CONSULTANT

AECOM
3rd Floor, East Wing
Plumer House
Tailyour Road
01752 676700

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KEY PLAN

DRAWING STATUS

INITIAL STATUS OR WIP

ISSUE/REVISION

P01.2	06/12/19	Cycle Route Added
I/R	DATE	DESCRIPTION

PROJECT NUMBER

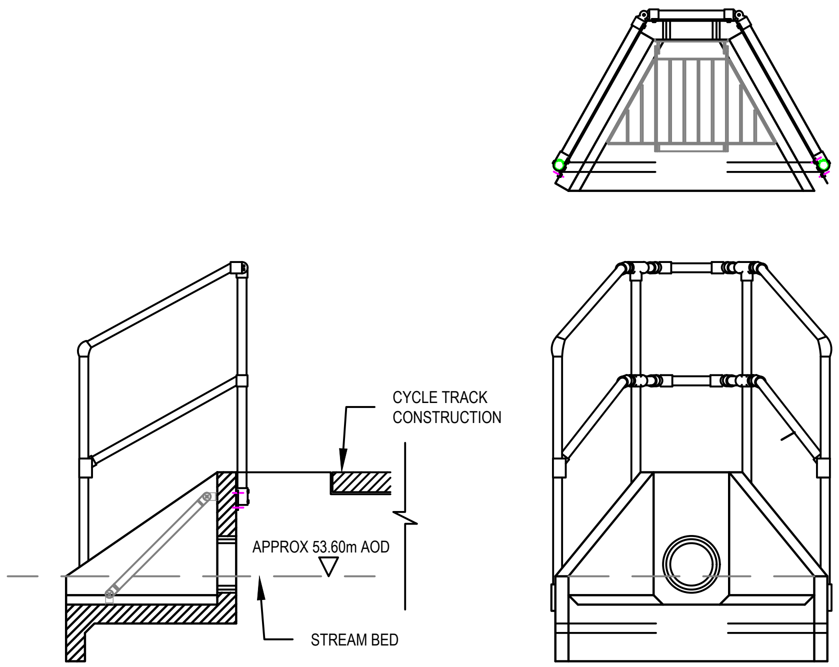
60535194

SHEET TITLE

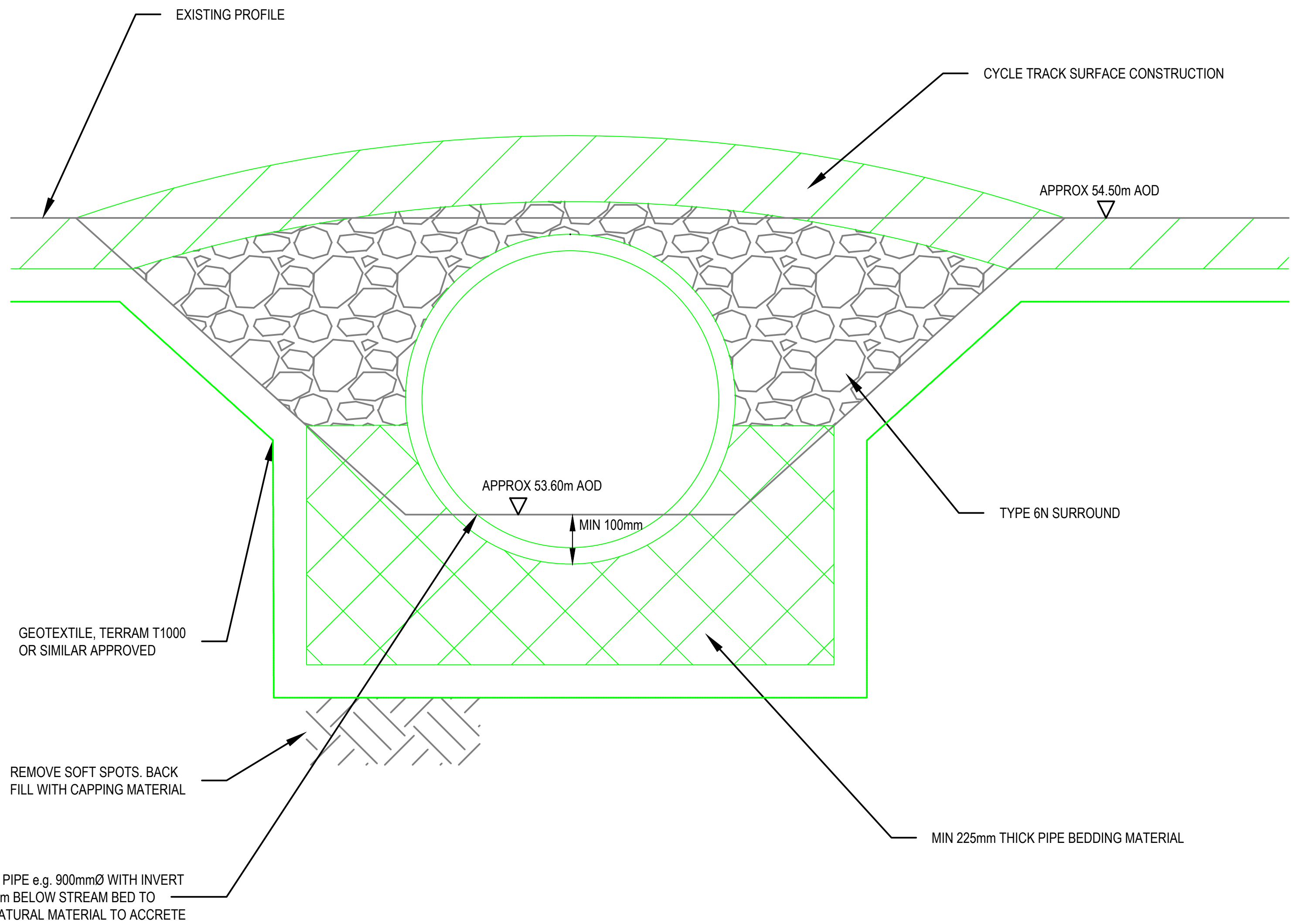
FVLR
COMMUNITY PARKS
BRIDGE SECTIONS
BRIDGE 1E

SHEET NUMBER **REV.**

FVLR-ACM-05-XX-DR-DR-00006 P01.2



TYPICAL PRE CAST CONCRETE HEADWALL DETAIL,
INSTALLED TO MANUFACTURER'S SPECIFICATION
NTS



TYPICAL LOCATION 1A SECTION THROUGH FORD CROSSING.
1:20

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PROJECT

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CONSULTANT

AECOM
3rd Floor, East Wing
Plumer House
Tailyour Road
01752 676700

DRAWING STATUS

INITIAL STATUS OR WIP

ISSUE/REVISION

I/R	DATE	DESCRIPTION
P01.2	06/12/19	Culvert Details Shown

PROJECT NUMBER

60535194

SHEET TITLE

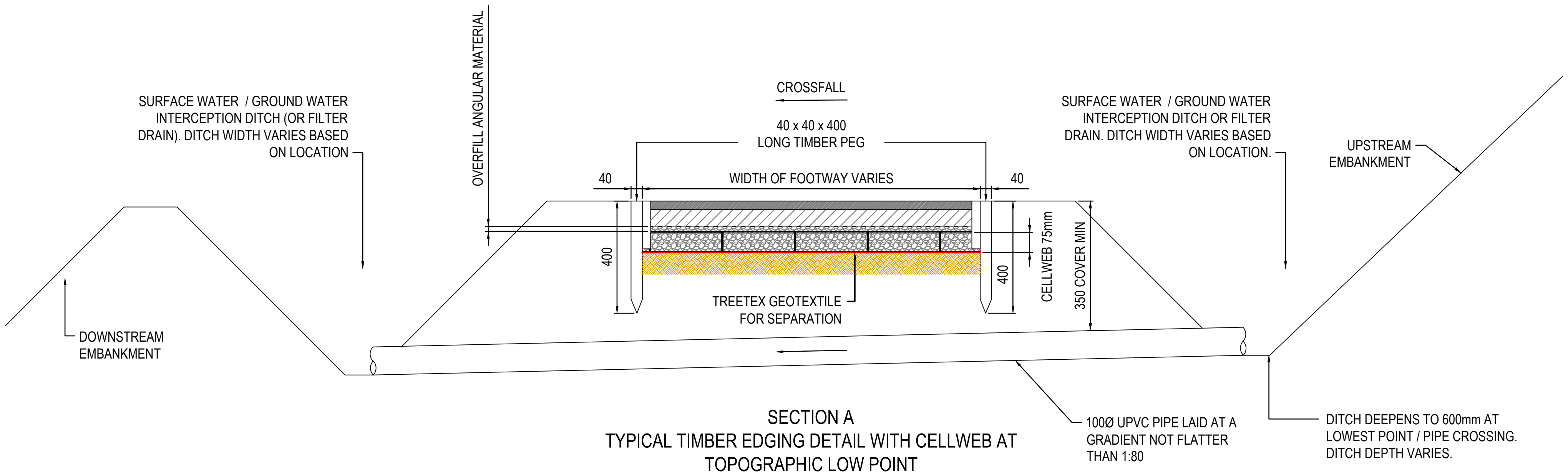
FVLR
COMMUNITY PARKS
CULVERT SECTION

SHEET NUMBER	REV.
FVLR-ACM-05-XX-DR-DR-00007	P01.2

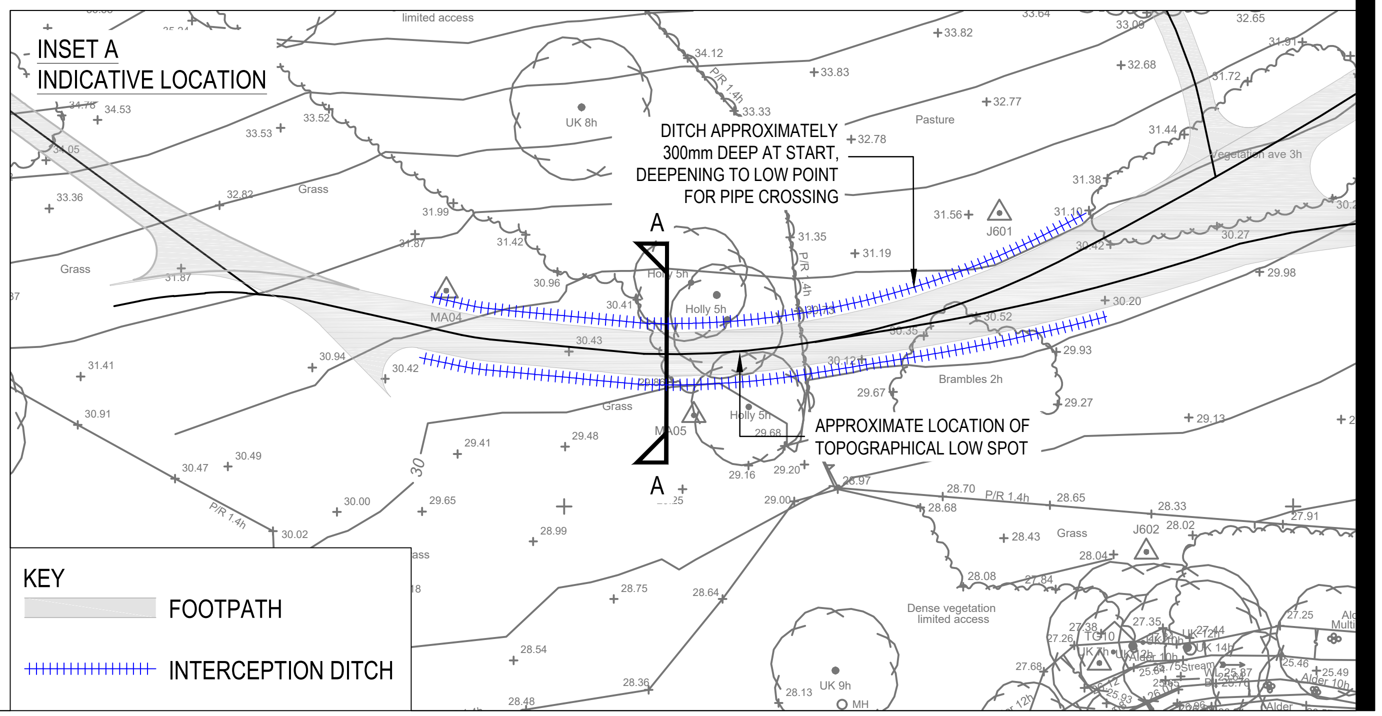
ISO A3 297mm x 420mm

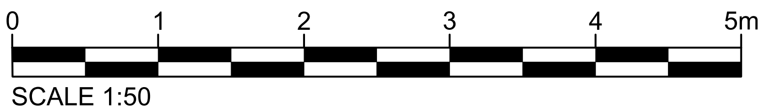
Approved: --- Checked: --- Designer: --- Project Management Initials: S0

Last saved by: PAUL.WHITHAM(2019-12-06) Last Plotted: 2019-12-06
Filename: C:\PWWORKING\AECOM_DS03_UK\PAUL.WHITHAM@AECOM.COM\DMS11690\FVLR-ACM-05-XX-DR-DR-00009.DWG



SECTION A
TYPICAL TIMBER EDGING DETAIL WITH CELLWEB AT TOPOGRAPHIC LOW POINT
(1:50)





AECOM

PROJECT

FORDER VALLEY LINK ROAD

CLIENT

BALFOUR BEATTY

CONSULTANT

AECOM
3rd Floor, East Wing
Plumer House
Tailyour Road
01752 676700

GENERAL NOTES

1. DO NOT SCALE FROM THIS DRAWING
2. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE STATED.
3. EXISTING GROUND LEVELS ARE BASED ON TOPOGRAPHICAL SURVEY INFORMATION.
4. DRAWING TO BE READ IN CONJUNCTION WITH FVLR BRIDGE SECTION 1D & 1E, REFERENCE FVLR-ACM-05-XX-DR-DR-00005 & 00006.

DRAWING STATUS

INITIAL STATUS OR WIP

ISSUE/REVISION

I/R	DATE	DESCRIPTION
P01.1	06/12/19	First Issue

PROJECT NUMBER

60535194

SHEET TITLE

CYCLE TRACK DRAINAGE
TYPICAL ARRANGEMENT

SHEET NUMBER REV.

FVLR-ACM-05-XX-DR-DR-00009 P01.1

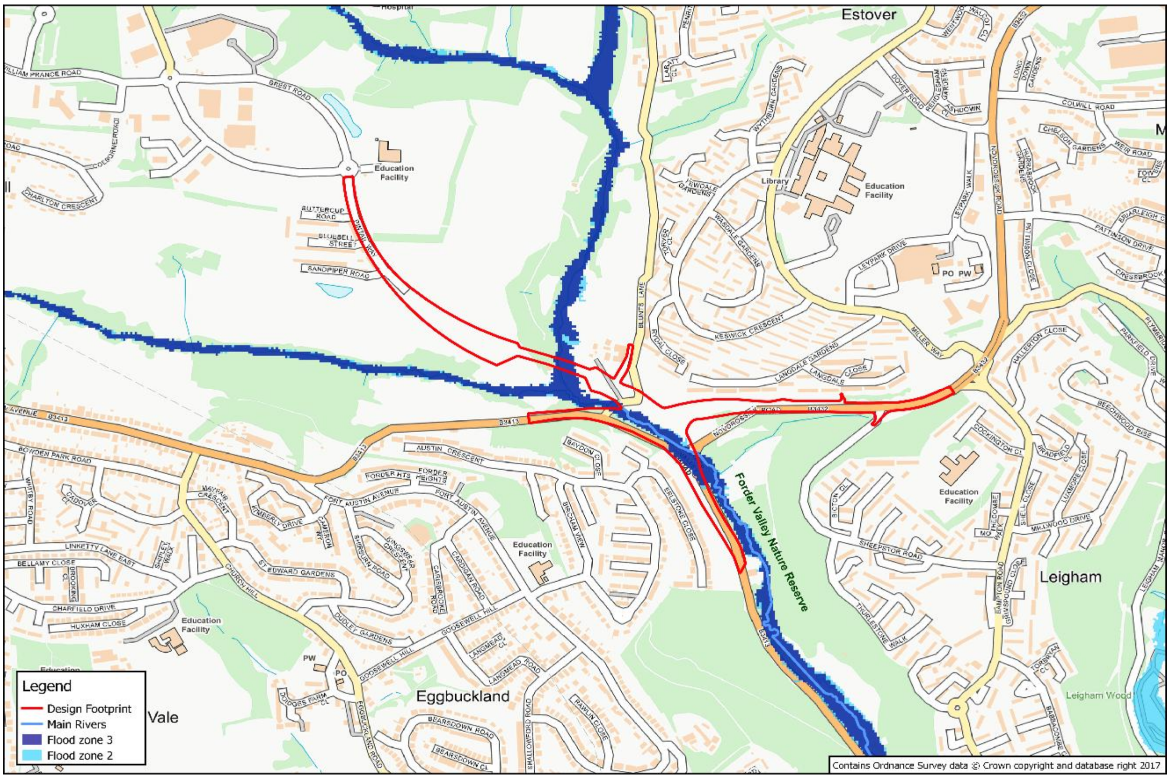
Appendix D Flood Data and Hydraulic Modelling

Appendix B

HYDRAULIC MODELLING LOG

Project	Forder Valley Link Road EIA
Job Number	70019161
Location	Plymouth, Devon (250418 058519)
Watercourse(s)	Forder Stream, Bircham Stream

1. Objectives/Areas of interest



WSP was commissioned by Plymouth City Council (PCC) to prepare a site specific Flood Risk Assessment (FRA) to support an Environmental Impact Assessment and planning application for a proposed development of the Forder Valley Link Road (FVLR). Review of indicative flood maps available from the Environment Agency (EA) website indicates that a large portion of the intended link road will reside within the low risk Flood Zone 1. However the intended works around the Blunts Lane crossing and the upgrade to the Forder Valley Road and Novorossiysk Road intersection will intrude on Flood Zones 2 and 3.

It is noted that in addition to the proximity to Flood Zones 2 and 3 the entire site sits within a "red problem" Critical Drainage Area which includes everything within the Forder Valley Stream catchment upstream of the A38. In particular there are records of historical flooding at Wilburt Road downstream of the prepared works. This flooding was attributed to the capacity of the stream being exceeded.

The Proposed Scheme consists of a link road from the roundabout at the William Prance Road and Brest Road junction in Derriford to the north to the Forder Valley Road and Novorossiysk Road junction to the south. This link road will include a large span bridge crossing the Bircham Valley and the upgrade of the existing junction between Forder Valley Road and Novorossiysk Road.

The development of the link road is part of the larger Seaton Neighbourhood Development in Derriford.

This development of the link road and the upgrade to the junction have the potential to have a
An initial review of the existing flood risk assessments and scheme proposals identified the need to complete detailed hydraulic modelling to support the FRA. As a previous model was unavailable a 1D baseline model was constructed using topographical survey completed within the forder valley in July 2017. The hydraulic assessment was then completed utilising this baseline model. The details of the survey and modelling are provided in this technical note.

2. Model Input Data

A digital copy of the data listed below has been provided in the '1 Model Input Data' folder.

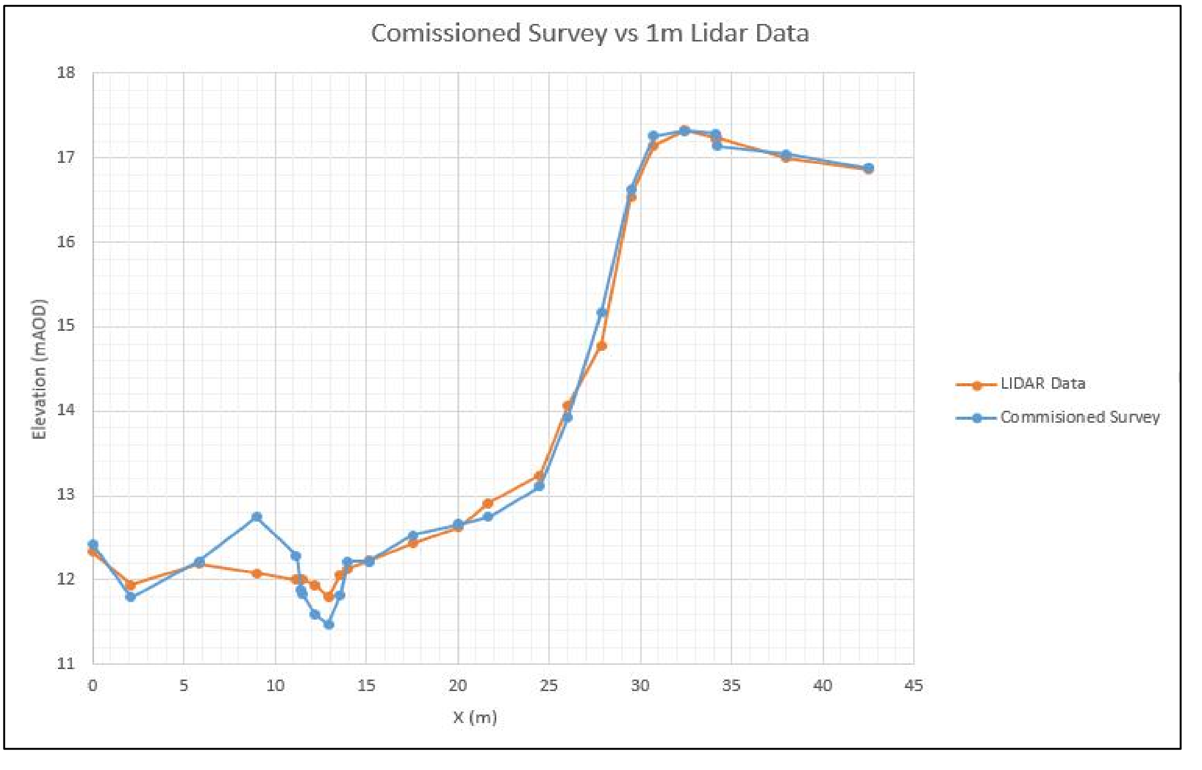
Title	Type	Notes
WS2150_BIRCHAM_STREAM_ISIS.dat	Topographic Survey	Detailed topographic survey of specific sections along the Bircham Brook. The location of these sections was determined during a preliminary site visit conducted by WSP. The data has been used to construct the river and structure sections within the model
WS2150_FORDER_STREAM_ISIS.dat	Topographic Survey	Detailed topographic survey of specific sections along the Forder Stream. The location of these sections was determined during a preliminary site visit conducted by WSP. The data has been used to construct the river and structure sections within the model
WS2150_01-07_XSEC_REVB.dwg	Detailed cross section drawings.	Detailed drawings of each section surveyed in the topographical survey. Includes details on dimensions of structures present withint he watercourses. Used to inform the creation of the required structures in the 1D model.
FVLR-ACM-00-05-DR-CE-0001 CULVERT LONGSECTIONS AND PLAN.pdf	Proposed design of culverts	Detailed design of culverts supplied by a consultant other than WSP.
FVLR-ACM-00-06-DR-CE-0001 BACK OF FOOTWAY LONGSECTION AND PLAN.pdf	Proposed design of road and embankment levels for use in creation of spill sections	Detailed design of road supplied by a consultant other than WSP.
FVLR-ACM-00-01-DR-CE-0004 B OUTLINE DESIGN GA.pdf	Proposed Road Design	Detailed design of road supplied by a consultant other than WSP.

3. GIS Data

OS Tiles - 10k: SX45 and SX55

LIDAR - Resolution: 1m
Date : LIDAR Composite - Data downloaded from environment.data.gov.uk June 2017. Date flown 2016

The below figure gives a comparison between the commisioned survey and the LIDAR survey at river section For924. The comparison shows that while there is a reasonable match between the survey and the lidar, the surveyed data provides increased detail around the river bed. Due to the similarity between the Lidar and survey in the overbank areas the Lidar was seen as sufficient when data in the overbank areas needed to be extended (e.g. in instances of glass walling where the cross-section needed to be widened).



4. Model Development

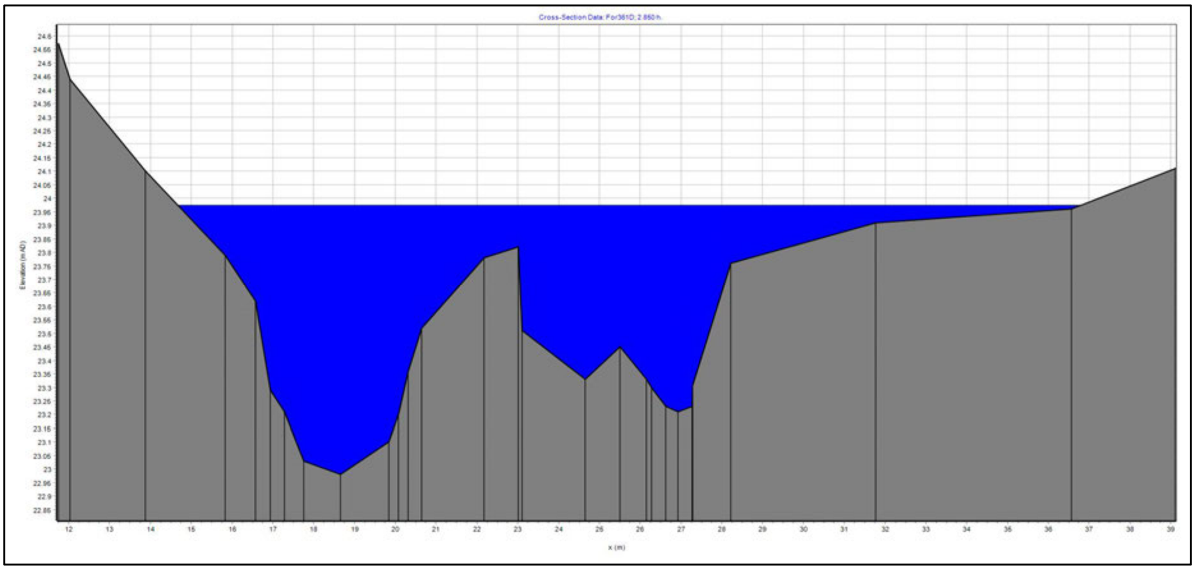
Baseline Model

The baseline modelling for this assessment has been constructed using topographical survey completed by Merrett Surveys Ltd in July 2017. The extent of the survey brief was informed by a site visit conducted on the 18th of May 2017.

The extent of the survey and hence the following baseline data was determined by an assessment of the existing water infrastructure onsite and the local topography compared with the initial proposed design. The steepness of the valleys led to the conclusion that the full extent of the Forder and Bircham valleys need not be modelled as flows in the upper reaches were unlikely to be affected by changes in the flow downstream.

It was noted in the initial construction of the model that the steepness of the watercourses led to an inherent instability in the model. In order to overcome this inherent instability some structures where approximated using simplified methods. Details of the method used to model each of the existing structures can be found in appendix A of this log

The confluence of the Forder and Bircham Streams is a short distance west of the crossing underneath Blunts Lane. The two watercourses run parallel to each other for approximately 50m upstream of the confluence and because the interneving embankment is low, the two channels have been represented as a single channel in the model for this reach. This approach was seen as acceptable as when the model is running peak flow situations for the tested events the bank section in between the streams is overtopped and the two streams act as a single unit. This arrangement also made a significant difference in model stability. The figure below shows an example cross-section of the water across the parralell watercourses during the peak of the main tested event.



It was noted later in the construction of the model that the position of the confluence was causing surcharging of the upstream forder reach. It was thought that this was because of the presence of 2 bed levels within the section immediately downstream of the models confluence leading to the model reading a sudden drop in bed levels over a 0m distance in the reach. In order to help with the processing of this drop an inline spill was introduced between the bottom end of the upstream Forder Reach and the confluence. This spill has the same cross-section as the river section immediately upstream of it.

Upstream reaches of the Forder and Bircham watercourses that were originally surveyed were removed from the model in order to aid stability. Due to the steepness of the watercourses these sections were seen to be having minimal effect on the flood extent in the downstream sections, while their inclusion in the model led to an increased instability.

The following sections have been created in the construction of the baseline model

- In order to increase the stability of the model various interpolated sections have been introduced using the inbuilt Auto-interpolate tool.

- The following sections have been duplicated upstream or downstream of themselves in order to preserve the length of the reach following the introduction of junctions or structures (Bir343D, For357D, For361D, For420D and For501)
- For351 was copied from For357 and created as an additional section 6m upstream. This was to facilitate a spill point that allowed cross-flow from section Bir351 located on the Bircham Stream reach. Onsite it was observed that the Bircham Stream overflowed in the direction of the Forder Stream. The movement of the models confluence to the point where the streams begin to run parallel negated the need for further spill units to be added downstream.
- The downstream extent of the model was extended with sections For1065 and For1156. This was done as it was anticipated that some proposed works may begin to influence the lower extents of the model and hence a comparison point beyond these final works would be needed. The sections were created using the base sections of For924 and For983 to build the initial levels for For1156 and For1065 respectively. The levels for these sections were then lowered to match the grade found between the two previous river nodes in the reach. These sections were then extended using the LIDAR survey present in their new locations.

Proposed Model Development

The proposed model was to be a basic update of the baseline model encompassing the introduction of a realigned channel to accomodate a new pier of the Bircham Valley Bridge and an engineered channel with 2 proposed culverts on the upstream and downstream ends to convey flow underneath the upgraded FVLR intersection. The inclusion of the culverts and engineered channel neccessitated the removal of the existing Novorossiysk Road culvert and the concrete obstruction within the stream. While these two structures would be removed because the new structures would be taking their place, the structure underneath Blunts Lane would also be removed as the road itself would be demolished once construction of the new junction was completed.

The Bircham Valley Brige design requires a bridge pier in the existing channel. The proposal is therefore to realign the channel to the west of the pier so that the new pier is on the stream bank. The revised alignment has been represented by adjusting the length of the channel to represent the new alignment, the resulting change in length was marginal as the pier is to be located in a small meander. The cross section data has been adjusted assuming the new channel profile will be the same as the existing but situated to the west. No changes to Manning's roughness were made as the channel curvature in pre and post proposals were similar.

In the creation of the FVLR intersection structures the sections For576, For621, For711 and their associated interpolates were created. The chainage for these sections was created by stepping back along the chainage from the downstream end of the proposed sections For711. It should be noted however that, as the proposed culverts and channel take a more direct route under the intersection than the baseline structures and watercourse, the overall length of the model has decreased by 25m. Because of this the distance between sections For476 and For576 is only 75m as opposed to 100m. It was decided that maintaining the names of the downstream sections in the reach would make processing of the model results simpler.

In removing the culvert associated with Blunts Lane it was assumed that the bed levels in the downstream area of the river bed would be graded to better match in with the rest of the stream.

The initial model of the culverts was based on the provided design drawings. There was however a discrepancy discovered between the levels provided by the designer and those found in the survey comissioned by WSP. As the road designers were basing their design on a basic topographic survey it was concluded that the discrepancy was due to the level of detail included in the different surveys. The survey commisioned in order to build the flood model was focused on the watercourses rather than the wider topographical detail and hence obtained a more detailed picture of the river bed. The designers noted that there were also areas that they had to rely on LIDAR survey as they were outside the extent of their topographic survey. WSP and the designers consulted on the difference between the 2 levels of survey and it was agreed that WSP would provide the required invert levels for the culvert based on the more detailed survey and the designers would move forward using these provided levels. These are the levels that have been used in the model.

Sizing of the proposed structures was done based on the need to accommodate a 600mm space for an otter shelf in the top of each of the proposed culverts. This spacing also had to be achieved at the inlet of each of the proposed culverts. The only restriction on the sizing was a maximum height of 2.4m for each culvert.

The proposed culverts and engineered channel were intended to have boulders included in the base in order to simulate a natural bed material. To simulate this the culverts and engineered channel were given a bed roughness similar to the river sections upstream and downstream of the culvert. However it was slightly reduced as it was deemed that while a natural bedlike structure could be constructed it would likely not be as rough as the existing river sections.

The inflow nodes of each of the proposed culverts were originally modelled as culvert inlet loss units. These units however kept producing unexpectadly large headloss values at the inlet even when the culvert being modelled was wider than the upstream river section. It was determined that this was because the culvert was adopting the headloss equations for inlet controlled flow as the worst case scenario. It could be shown however that the proposed culverts were all flowing in subcritical outlet controlled flow regimes for their entire length. In order to have the culvert model a more realistic inlet headloss a general headloss unit was substituted for the inlet unit and given an inlet loss coefficient appropriate for an outlet controlled channel.

The use of general headloss units for the inflow nodes meant that the standard option to include a trash screen was not available for the inflow nodes (this option can be added in as standard to culver inlet loss units). In order to account for the inclusion of trash screens on the proposed culverts an adjustment was made to the loss coefficient of the general headloss nodes. This was done by calculating the headloss for the peak of the 100 year plus 40% climate change event using both the general headloss equation and the equation for headloss due to a trash screen. These values were then added together and fed back through the general headloss equation with the adjusted headloss coefficient left as the unknown factor (see equations below).

General Headloss Equation

$$\Delta h_g = \frac{K_g V^2}{2g}$$

Trash Screen Headloss Equation

$$\Delta h_T = \frac{K_T Q^2}{2g[y_i W_s]^2}[\frac{1}{S^2}-1]$$

Combining the headloss from each of the above equations will allow for the calculation of an adjusted headloss coefficient in the form of K_a

$$\Delta h_g + \Delta h_T = \frac{K_a V^2}{2g}$$

$$K_a = \frac{2g(\Delta h_g + \Delta h_T)}{V^2}$$

As the introduction of the road embankment will affect some of the local topography upstream of the proposed culverts some alterations have been made to the river sections in this area. As far back as For420 the sections have been edited to include the extent of the road embankment. The embankment extent, slope and height were informed by the pdf drawings provided by the designers.

The road embankment that borders the nature reserve south of the proposed culverts includes a steep reinforced earthen slope. This is so that the embankment extents do not overide the area of the watercourse in the reserve. To account for this steep embankment wall in the model the sections For711, For804 and For924 have been edited to include this embankment as a vertical wall on one side of the alignment. The embankment extent, slope and height were informed by the pdf drawings provided by the designers.

5. Model Setup

Model Method	1D
Software	FMP (4.2.6050.22474)
Channel and Floodplain	1D surveyed sections modelled using ISIS
Run Settings	Unsteady simulation (adaptive timestepping)
Other comments	In the setup of each of the model simulations the initial conditions were established using the steady flow run type. These conditions were then replaced with a set of conditions created using an unsteady flow run type once a full event could be run with stability. Other than the reduction of the timestep, changes in start and finish times and the save interval used, all other run settings have been left as the default set by flood modeller pro

6. Model inflows and Boundary Conditions

A review of the topography of the watercourses onsite led to the development of 3 inflow nodes for the model. A node covering the extent of each watercourse upstream of the confluence and a single node covering the flow produced in the area downstream of the confluence.

Peak flows have been derived from a statistical assessment for the site. ReFH2 has then been used to derive the hydrograph, which has been scaled to the calculated peak flows.

Flow Node	Annual Probability Event							
	5	25	50	100	200	100+40%CC	100+85%CC	1000
For000	1.34	1.97	2.33	2.76	3.29	3.87	5.11	5
Bir119	2.8	4.14	4.89	5.8	6.91	8.12	10.73	10.49
FL-flow	0.72	1.07	1.26	1.5	1.78	2.1	2.77	2.71

The design event for the assessment is the 1 in 100 annual probability event plus 40% climate change, which is equivalent to the Higher Central Climate Change allowance for the site. The impacts of the 1000 year return period and the 100 year +80% return period have also been assessed to understand residual risks. As the 100 year +80% is actually the larger of these two events the 1000 year event has not been run.

The downstream extent of the model was set as a normal depth boundary. The slope calculation was based on a user defined slope of 1 percent, derived from the local channel gradient.

7. Mannings 'n' Roughness Coefficients

The Manning's roughness coefficient values used in the baseline and proposed model are listed in the table below.

Description	Manning's
Baseline Model	
Channel - Forder Stream upstream of confluence	0.08
Channel - Bircham Stream	0.08
Channel - Forder Stream downstream of confluence	0.07
Existing overbank areas	0.100
Forder Stream Culvert Invert, Walls and Soffit (Fc210U, Fc210D)	0.040
Blunts Lane Culvert Invert (Fc454U, Fc454D)	0.070
Blunts Lane Culvert Walls, Soffit and Spill area (Fc454U, Fc454D)	0.040
Novorosiyssk Road Culvert Invert, Walls and Soffit (Fc641U, Fc641D)	0.020

Proposed Model	
Engineered Channel Low Flow Base (proposed to contain small boulders to simulate a natural channel)	0.06
Engineered Channel Base outside low flow area (Proposed to grass area with some plants)	0.04

Engineered Channel Embankment (Proposed to grass area with some plants)	0.04
Proposed Culvert Inverts (proposed to contain small boulders to simulate a natural channel)	0.06
Proposed Culvert Walls and Soffit (relatively smooth as a precast concrete section)	0.011

8. Model File Naming Convention

Initial Setup
File name: FVLR_BASE_PPP_****_C##_@@@_CUT?

e.g. FVLR_BASE_FOR_0100_C85_002_CUT2

FVLR	Forder Valley Link Road FRA hydraulic model
BASE	Baseline topography
PPP	The watercourse reach (as detailed below)
****	The return period that is being modelled - for example '0100' where 0100 indicates 100 year fluvial event
C##	Climate change allowance (e.g. C85 = 85% increase in fluvial flows. Note - C00 is used to indicated present day and INT indicates the use of a base event in order to setup the initial conditions)
@@@	This will represent the build number of the model
CUT?	Due to the instability in the overall model the baseline had to be constructed by gradually building up each watercourse and dealing with instability issues before adding another "CUT" to the reach. 4 Cuts were used to construct the Bircham stream reach and 6 cuts where used in order to construct the Forder Stream reach.

Running Model
File name: FVLR_SSSS_****_C##_@@@

e.g. FVLR_BASE_0100_C85_003

FVLR	Forder Valley Link Road FRA hydraulic model
SSSS	The model scenario (as detailed below)
****	The return period that is being modelled - for example '0100' where 0100 indicates 100 year fluvial event
C##	Climate change allowance (e.g. C85 = 85% increase in fluvial flows. Note - C00 is used
@@@	This will represent the build number of the model

Topographical Model Scenarios

BASE	Baseline model
PROP	Plymouth City Council Proposals (Culverts, channels and bridge structures to be

Watercourse Reach (for initial setup)

FOR	Forder Stream
BIR	Bircham Brook

9. Model Runs

Model Scenario	Return Periods / Events	Comments
Baseline (BASE)	5 year, 25 year, 50 year, 100 year, 200 year, 100 year +40%, 100 year +85%	
Proposed Scheme (PROP)	5 year, 25 year, 50 year, 100 year, 200 year, 100 year +40%, 100 year +85%	

Roughness Sensitivity Analysis (BRUH) Based on the baseline build FVLR_BASE_018	100 year +40%	Test sensitivity of the model to the roughness by running an increase of 20% and decrease of 10% to the manning's n of the model
Roughness Sensitivity Analysis (PRUH) Based on the proposed build FVLR_PROP_018	100 year +40%	Test sensitivity of the model to the roughness by running an increase of 20% and decrease of 10% to the manning's n of the model
Downstream Slope Sensitivity Analysis (SLOP) Based on the baseline build FVLR_BASE_018	100 year +40%	Test sensitivity of the downstream boundary by running an increase and decrease of the normal slope boundary
Blockage Analysis (BLOC) Based on the proposed build FVLR_PROP_018	100 year +40%	Blockage tested for both culverts simultaneously (001) and the upstream (002) and downstream (003) culvert blocked individually.

10. Model Results

Baseline

The results of the baseline model show the Forder and Bircham watercourses to be quite "flashy". The modelled hydrology shows that the valleys produce storms that have high peak flows for shorter durations. This is reflected in the high water levels present in the peak of each event. This "flashy" nature of the watercourses can likely be attributed to the steepness of the side of the valleys the watercourses reside in. In addition the steep nature of the watercourses themselves also results in changes in the water infrastructure having a minimal effect on the watercourse upstream. This was confirmed in the sensitivity tests conducted on the downstream slope boundary for the model outlined in section 11.

The high peaks in the model lead to flood risk at the modelled crossings. The Blunts Lane culvert is shown to experience a certain amount of overtopping in each of the modelled events. Ranging from the 1 in 5 year event where it is shown to have a water depth of approximately 200mm at the lowest point of the road, to the 100 year event plus 80% climate change exceedance event where the road sits under 900mm of water. The existing Novorossiysk Road and Forder Valley Road intersection that the Forder Valley Link Road will connect to is also at risk of overtopping. In events above the 50 year this intersection is shown to have between 200 and 600mm of overtopping flow.

The flood risk posed to these two intersections in the model confirms the risk shown in the EA's flood map for planning. The Novorosiyssk Road junction and Blunts Lane crossing are shown to sit within Flood zone 3 with the surrounding areas also becoming inundated. This level of flooding presents risks to both the natural environment as well as members of the public. However the proposed upgrades involved with the Forder Valley Link Road present the opportunity for betterment in reducing the overall flood risk to the road.

Proposed
The proposed model shows significant reduction in the flood risk to the upgraded intersection and surrounding road. This can be attributed to the increase in the size of the culverts underneath the intersection, as well as the raising of the level of the intersection overall. The result of these changes is that in the proposed model the upgraded intersection doesn't experience any overtopping for the modelled events. The upgrades to the Forder Valley Road west of the proposed intersection have also raised this area above the peak flood level of the model.

In the nature reserve downstream of the proposed intersection, changes to the extent of the road embankment reduce the width of the floodplain on the right bank. Due to the steep sides of the valley the model does not indicate any large increase in the flooded extent on the left bank in this area with an increase in flood width within the nature reserve of only 200mm in the peak of the tested event (100yr +40% climate change). The reduction of the existing flood storage in the nature reserve could also lead to more flow being pushed downstream. With the site being in a "red problem" Critical Drainage Catchment this extra flow could have a detrimental affect on properties downstream with a history of flooding. A comparison between the baseline and proposed models shows negligble changes in the velocity, flow and water level at the downstream extent of the model. A further examination of the model shows that in consecutive river sections throughout the model, other than a slight shift in the overall timescale explainable by the additional distance that the flow travels between the sections, there was no change in the overall flow hydrograph. This would imply that the watercourse is simply converying flow and not providing attenuation within the valley. So while some area that could be percieved as flood storage has been taken up in the nature reserve it does not affect the overall flow downstream as the existing stream does not provide attenuation of flood flows

The reduction in the flood risk to the junction with the link road and the lack of impact on the watercourse downstream of the model would indicate that overall the proposed works have a beneficial effect on the flooding in their immediate area while at the same time not increasing the flood risk to the connected water environment.

11. Model Sensitivity Analysis and Residual Risk Simulations

This section provides a decription of the residual risk and sensitivity analysis that has been completed.

Downstream Slope Boundary
To test the sensitivity of the baseline model to changes in the downstream boundary tests were conducted raising and lowering the normal slope boundary. The tested slopes were 1 in 50, 1 in 100 (standard boundary set in the baseline and proposed model), 1 in 200, 1 in 500 and 1 in 1000.

While the changes in the normal slope boundary has an effect on downstream most sections of the model the effect of the boundary change does not affect water levels in the vicinity of the proposals. This is due to the steep gradient of the watercourse. Due to this lack of effect upstream to the changes in the downstream boundary it was deemed that the model was not very sensitive to changes in this boundary. It was also deemed that the same sensitivity test was not required for the proposed model as the affected sections in the downstream end of the model have not changed between the baseline and proposed.

Roughness Coefficient
To acertain the sensitivity of the model to changes in roughness tests were conducted increasing and decreasing the overall roughness of the model. The roughness was increased by 20% overall and initially the same decrease was to be applied. However after numerous iterations it was determined that any decrease in the roughness of more than 10% led to the model becoming unstable and a complete run of the design event could not be achieved. As such a decrease of 10% was tested. These tests were done on both the baseline and proposed builds of the model.

As expected the raising and lowering of the overall model roughness produced relative rises and drops in the water level along the length of the model. While the amount of water level change across the model differs depending on the section, the average change is approximately 3% - 4% for every 10% change in roughness. There are similar percentage rises and drops in the velocity of each section while the maximum flow through each section remains relatively unchanged.

Blockage Assessment

The modelling of the Proposed Scheme assumes that the system works as designed. The residual risk from a blockage occuring has been assessed. Three scenarios were assessed for the blockage assessment; the simultaneous 50% blockage of both of the proposed culverts and the 50% blockage of each culvert individually while the other remains unblocked. During each of these scenarios the water level within each of the partially blocked culverts increased until they were surcharging and flowing full. However while the water level did increase it did not reach a height where it would spill over the road. As such it is deemed that a large blockage of the culverts presents a minimum risk to the overall scheme.

Appendix A. Structures

Baseline Model

Ref.	Description	Data source	Dimensions	Modelling Approach
1	Poole Farm access track crossing and culvert. Structure was quite dilapedated onsite. Presented in section XS05-A	WS2150_01-07_CROSS_SECTIONS_REVA.dwg	1 x 300 RCP invert inlet:23.23m Top of causeway sits at 24.25m	The causeway was modelled as a spill section. The culvert present in the causeway was not modelled. During the onsite visit it was seen that the causeway and culvert where in disrepair. It was decided that the culvert could be considered to be blocked and hence not modelled.
2	Culvert crossing of Forder Stream. Upstream of Confluence with Bircham stream. Presented in section XS08-B	WS2150_01-07_CROSS_SECTIONS_REVA.dwg	1x340mm RCP inlet: 27.12m outlet: 26.48m rectangular opening approx 700mm x 800mm Inlet: 26.8m outlet: 26.09m	The culvert has been modelled using rectangular sections. The pipe section of the culvert was not modelled. During the onsite visit it was noted as being in disrepair and partially filled with debris. The pipe section of the culvert was not modelled in order to assist with model stability. Due to the potential for the pipe section of the culvert to become blocked its exclusion was considered reasonable as it wold lead to a conservative assumption of the culverts flow.
3	Concrete footbridge spaning both Bircham and Forder streams just upstream of their confluence. Presented in section XS11	WS2150_01-07_CROSS_SECTIONS_REVA.dwg	Approximately 31m length. Split into 4 irregular spans. 2.7m, 7.1m, 6.3m, 14.3m varying deck level ranging from 24.46m to 24.57m. Deck thickness: 0.275m	The Bridge is modelled as an USBPR Bridge section. Soffit level is set as 24.24 mAOD as determined from provided cross-sections. The section of the bridge has been restricted to the inner span of the bridge. A spill section has been used to model overtopping of the bridge. This spill includes the extended section and overbank areas around the bridge.
4	Culvert under Blunts Lane. Structure also includes high barriers around the edge of the road to protect vehicles from falling into creek. These structures would also impede overtopping flows. Presented in section XS14-B	WS2150_01-07_CROSS_SECTIONS_REVA.dwg	Approximately 1.9m by 1.2m rectangular opening on upstream end. Uneven bed level with base inlet invert of 19.7m. Downstream opening is an arch with base width of 1.01m. Arch height of 0.3m. Base level of outlet invert 19.8m	The culvert under Blunts lane has been modelled using sprung arched conduit sections. Due to the inability for flood modeller to handle the change of cross-section across conduit units in a single reach the opening for the culvert has been based on the smaller downstream outlet. However the inlet losses associated with the culvert have been calculated based upon the existing rectangular opening. A spill section has been used to model overtopping of the culvert. The spill section includes the safety barriers alongside the bridge.

5	Concrete obstruction in flow downstream of Blunts Lane Culvert. A small pipe is present through the structure. Presented in section XS16-B	WS2150_01-07_CROSS_SECTIONS_REVA.dwg	Obstruction has an irregular shape. Pipe through structure 1 x 260 RCP invert 19.31m. Crest top of structure 20.4m. Maximum width of structure in stream 2.5m	The concrete obstruction in the flow has been modelled as a Bernoulli Loss section. Areas for the calculation of the loss coefficients were measured from the drawing cross-sections. For the calculations the conveyance of the section was assumed to be directly proportional to the flow area.
6	Culverts under Novorossiysk road. Trash screen present across culvert inlet. Presented in section XS18-B	WS2150_01-07_CROSS_SECTIONS_REVA.dwg	Culverts 2 x 1250 RCP Inlet 16.31m. Outlet 15.75m. Outlet end of pipes partially embeded in ground level by approximately 370mm.	The twin existing culverts underneath Novorossiysk Road have been modelled using parallel circular conduit sections. The partially embeded nature of the outlet end of the pipes has not been accounted for in the model. The spill section for modelling of the overtopping has been created using the provided upstream section of the culvert and road levels taken from existing topographic survey received on the 24th of April.

Proposed Structures

Ref.	Description	Data source	Dimensions	Modelling Approach
8	Temp Bridge 2. Upgrade to Poole Farm access track crossing. For farm users and temp works traffic. Will be left as a permanent feature	No data has been provided as yet. Location will be based on location of previous structure.	As no data has yet been provided on this structure the dimensions have not yet been determined.	As details of the structure have not been provided it will remain unchanged within the proposed model. This will act as a conservative assumption for the modelling of the proposed structure which is anticipated to be more efficient than the existing.
9	North West Culvert underneath the upgraded junction.	FVLR-ACM-00-05-DR-CE-0001 CULVERT LONGSECTIONS AND PLAN.pdf	Initial dimensions provided where 1800 x 2400 RCBC. Winged headwalls. 74m length measured from provided pdf drawing. Invert levels have not been provided. Of the initial dimensions the height was set as unable to be increased. The width could be changed within the model to reach required compliance levels.	The culvert has been modelled using rectangular conduit sections. The river section For476 has been used as the location of the river inlet. The downstream invert will be based on the grade brought back from the downstream end of the proposed structures
10	Engineered channel connecting the proposed culverts underneath the upgraded Junction of Forder Valley and novorossiysk Road.	FVLR-ACM-00-05-DR-CE-0001 CULVERT LONGSECTIONS AND PLAN.pdf	The initial Base of channel is an open box section 2.7m wide by 2.1m high. During modelling the dimensions will be iterated to reach a compliant water level within the adjacent culverts. Fill slopes beyond the channel height extend at a slope of 1:1.5. Intended to be 2 stage channel where possible. Low flow channel design has been informed by notes from the ecologist. Channel length of 45m has been measured from the provided PDF.	The engineered channel will be modelled using river sections to be set as the downstream and upstream sections of the connecting culverts. The bed levels of these sections will be based upon the translated invert levels from the provided design. The low flow channel will be modelled in the river sections. The depth of the low flow channel has been set at 300mm while the width will be set at two thirds of the upstream culvert width.

11	South East culvert underneath the upgraded junction. Intended to replace the existing culvert under Novorossiysk Road. The location of the new culvert has been adjusted from the previous culverts location to account for changes in the embankment of the road.	FVLR-ACM-00-05-DR-CE-0001 CULVERT LONGSECTIONS AND PLAN.pdf	1800 x 2400 RCBC. Winged headwalls. Total culvert length of 90m given in long section detail. The grade of the culvert has been edited along with the invert levels that have been lowered to coincide with the more detailed survey comissioned by WSP.	The culvert has been modelled using a rectangular conduit. The initial invert levels of the culvert have been matched into the detailed survey bed levels.
12	Bircham Stream proposed bridge pier. One of the proposed bridge piers is to be placed directly in the current alignment of Bircham Stream. Proposals are to realign the watercourse around the western side of the pier. This will marginally increase the length of the stream in this location.	60535194-ACM-00-M3-0005.pdf	The pier itself will be located on the right bank. This has not been included in the model as flood flows in all events do not exceed bank top. The channel capacity through this reach has been estimated from LIDAR with sections extracted from upstream of the bridge, adjacent to the pier and downstream of the bridge. The resulting sections compare well with the existing gradient in the channel.	The revised alignment has been represented by adjusting the length of the channel to represent the new alignment. The cross section data has been adjusted assuming the new channel profile will be the same as the existing but situated to the west. No changes to Manning's roughness were made as the channel curvature in pre and post proposals were similar.

Appendix B. Model Cross-Sections Schedule

The following table provides details of the model cross-sections. Sections that have been removed are listed here but have been crossed out. The reason for their removal has been listed in the additional comments. Interpolate sections, Junctions and Replicate sections have not been included in this list.

Label	Orginal Data Source	Additional Comments	X	Y	Left Bank Mannings	Channel Mannings	Right Bank Mannings	Channel Length	Invert	Left Bank Elevation	Right Bank Elevation
Initial sections provided by Surveyors											
For000	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0000. Corresponds to section XS06		250029.5	58472.33	0.07	0.06	0.07	19.000	32.01	33.71	37.64
For133	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0133. Corresponds to section XS07		250146.46	58445.75	0.1	0.08	0.1	9.860	29.31	31.43	35.27
For202	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0202. Corresponds to section XS08-A		250210.71	58426.29	0.1	0.08	0.1	8.000	27.09	30.55	36.74
For210	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0210. Corresponds to section XS08-B		250219.32	58425.38	0.1	0.08	0.1	0.000	26.77	31.12	36.36
For217	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0217. Corresponds to section XS08-C		250225.11	58428.11	0.1	0.08	0.1	7.000	26.07	30.94	35.86
For224	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0224. Corresponds to section XS08-D		250231.2	58432.28	0.1	0.08	0.1	4.560	25.99	30.91	35.59
For265	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0265. Corresponds to section XS09		250270.04	58437.21	0.1	0.08	0.1	4.780	25.15	29.2	31.73
For357	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0357. Corresponds to section XS10. Disabled overlap with Bircham Stream. Lateral spill to be introduced.		250333	58438.44	0.07	0.07	0.07	4.000	22.99	24.11	24.27
For361	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0361. Corresponds to section XS11. Disabled overlap with Bircham Stream. Lateral spill to be introduced.		250335.8	58436.89	0.07	0.07	0.07	4.830	22.98	23.78	25.09
For390	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0390. Corresponds to section XS12. Disabled overlap with Bircham Stream. Lateral spill to be introduced.		250355.26	58420.54	0.1	0.08	0.1	30.000	21.95	23.73	25.21
For420	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0420. Corresponds to section XS13		250388.8	58407.73	0.07	0.05	0.07	4.860	21.12	23.7	23.64

For454	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0454. Corresponds to section XS14-A		250422.17	58403.65	0.1	0.07	0.1	0.000	19.91	23.61	24.38
For457	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0457. Corresponds to section XS14-B		250423.49	58400.97	0.1	0.07	0.1	6.000	19.69	21.65	20.99
For463	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0463. Corresponds to section XS15-A		250430.22	58399.82	0.1	0.07	0.1	13.000	19.8	21.49	21.74
For476	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0476. Corresponds to section XS15-B		250441.36	58400.41	0.1	0.07	0.1	6.000	19.9	23.1	23.87
For493	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0493. Corresponds to section XS16-A		250455.21	58389.4	0.1	0.07	0.1	0.000	19.41	22.44	23.69
For498	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0498. Corresponds to section XS16-B		250458.52	58387.29	0.1	0.07	0.1	3.000	18.43	20.94	20.28
For501	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0501. Corresponds to section XS16-C		250460.16	58385.07	0.1	0.07	0.1	8.826	19.13	22.32	21.65
For563	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0563. Corresponds to section XS17		250510.72	58357.52	0.1	0.07	0.1	9.860	17.83	22.36	24.42
For632	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0632. Corresponds to section XS18-A		250562.43	58314.59	0.1	0.07	0.1	9.000	16.42	19.88	20.49
For641	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0641. Corresponds to section XS18-B		250568.74	58308.63	0.1	0.07	0.1	0.000	16.26	19.95	21.21
For689	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0689. Corresponds to section XS19		250611.16	58290.48	0.1	0.07	0.1	9.585	15.75	21.47	18.54
For804	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0804. Corresponds to section XS20		250660.08	58200.16	0.1	0.07	0.1	10.000	13.74	15.47	17.75
For924	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0924. Corresponds to section XS21		250703.5	58104.81	0.1	0.07	0.1	9.835	11.48	26.49	36.77
For983	WS2150_FORDER_STREAM_ISIS.dat. Previously CH0983. Corresponds to section XS22		250741.27	58063.31	0.1	0.07	0.1	82.000	10.82	30.29	37.92
Bir000	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0000. Corresponds to section XS01		250373.6	58768.28	0.07	0.06	0.07	5.000	40.68	46.42	42.38
Bir040	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0040. Corresponds to section XS02		250363	58726.78	0.07	0.06	0.07	9.875	37.59	41.77	39.12

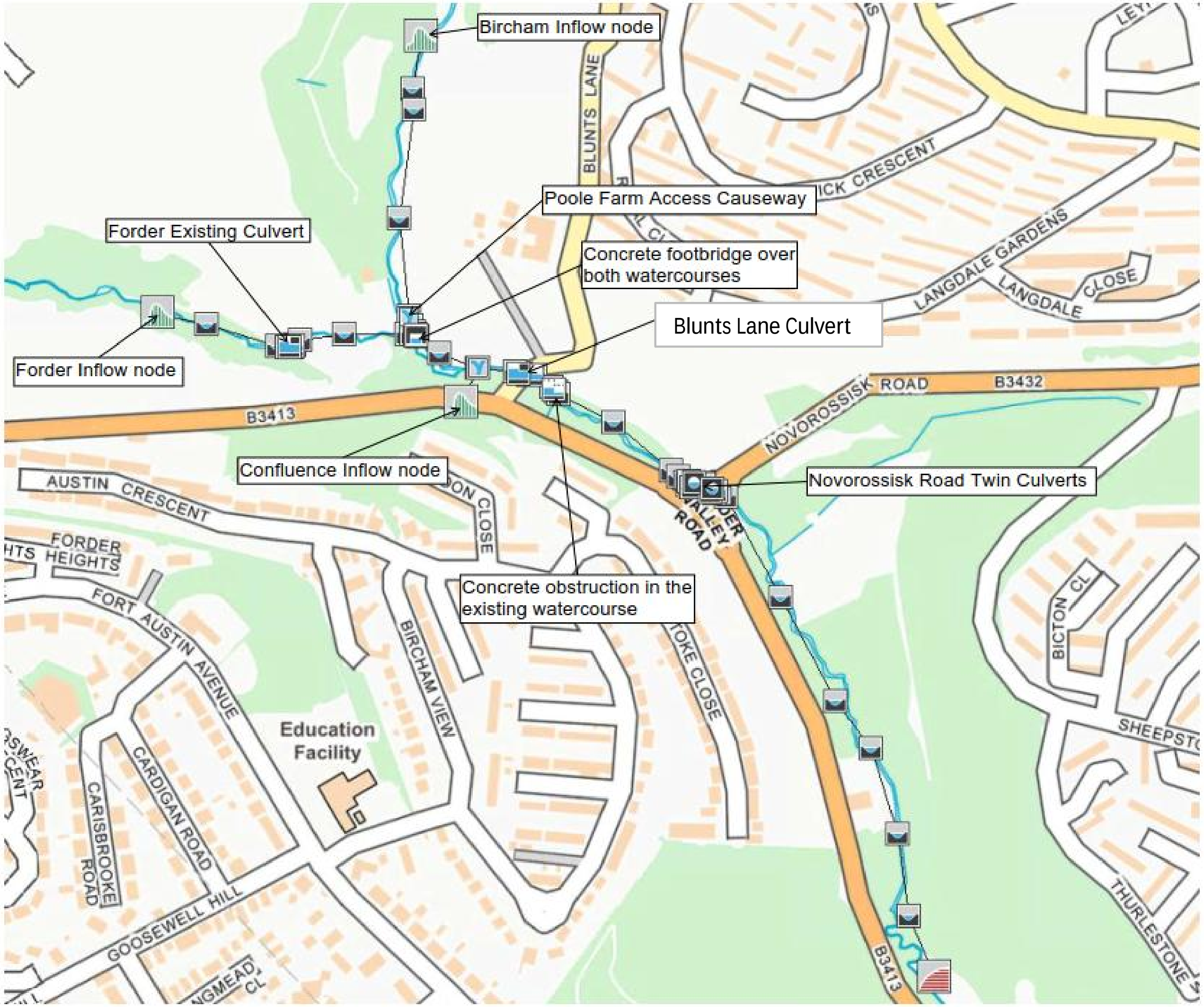
Bir119	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0119. Corresponds to section XS03-A		250330.68	58658.63	0.1	0.08	0.1	18.000	32.83	35.71	34.34
Bir137	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0137. Corresponds to section XS03-B		250332.22	58640.34	0.1	0.08	0.1	28.800	32.12	34.66	33.67
Bir245	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0245. Corresponds to section XS04		250319.11	58541.98	0.1	0.08	0.1	9.800	27.33	29.34	30
Bir305	Interpolated section to represent locations of proposed pier in channel		250306.39	58485.21	0.1	0.08	0.1	27.680	24.55	25.65	25.77
Bir343	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0343. Corresponds to section XS05-A		250326.8	58452.28	0.07	0.06	0.07	8.000	23.55	25.39	24.81
Bir351	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0351. Corresponds to section XS05-B. Disabled overlap with Forder Stream		250330.45	58444.74	0.1	0.08	0.1	3.000	23.07	24.98	24.19
Bir357	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0357. Corresponds to section XS10. Disabled overlap with Forder Stream. Lateral spill to be introduced.		250333.11	58438.36	0.1	0.08	0.1	0.000	22.99	24.71	24.11
Bir361	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0361. Corresponds to section XS11. Disabled overlap with Forder Stream. Lateral spill to be introduced.		250335.8	58436.89	0.07	0.06	0.07	4.830	22.98	24.53	23.82
Bir390	WS2150_BIRCHAM_STREAM_ISIS.dat. Previously CH0390. Corresponds to section XS12. Disabled overlap with Forder Stream. Lateral spill to be introduced.		250355.2	58420.54	0.07	0.06	0.07	29.000	21.95	23.73	23.66
Created Existing and Proposed sections											
For1065	Cross-section created by copying the base section of For983. The overall level was lowered using the grade from the last 2 sections of the reach to account for the drop in level over the newly created distance.		250764.9	57986.28	0.1	0.07	0.1	91.000	9.9	37.13	33.27
For1156	Cross-section created by copying the base section of For924. The overall level was lowered using the grade from the last 2 sections of the reach to account for the drop in level over the newly created distance.		250774.3	57912.66	0.1	0.07	0.1	0.000	8.88	30.6	32.43

For711	Cross section was created using a copy of the section For689. The position of the section was determined from the culvert design received on the 7th of September	Overall level of the section was lowered to account for the change in level as the section moves downstream. Section edited to remove shape of gabions as proposed culvert will have a designed headwall. Right overbank area of section edited to include retaining wall on edge of road alignment.	250632.16	58267.48	0.1	0.07	0.1	18	15.298	21.018	19.96
For621	Engineered channel section created in Excel to be the upstream section of the SE proposed culvert. Vertical levels based on invert determined by grading back from the section For711 at the designed grade.		0	0	0.04	0.06	0.04	0	16.996	23.096	23.096
For576	Engineered channel section created in Excel to be the downstream section of the NW proposed culvert. Vertical levels based on invert determined by grading back from the section For621 at the designed grade.		0	0	0.04	0.06	0.04	9	17.845	23.945	23.945

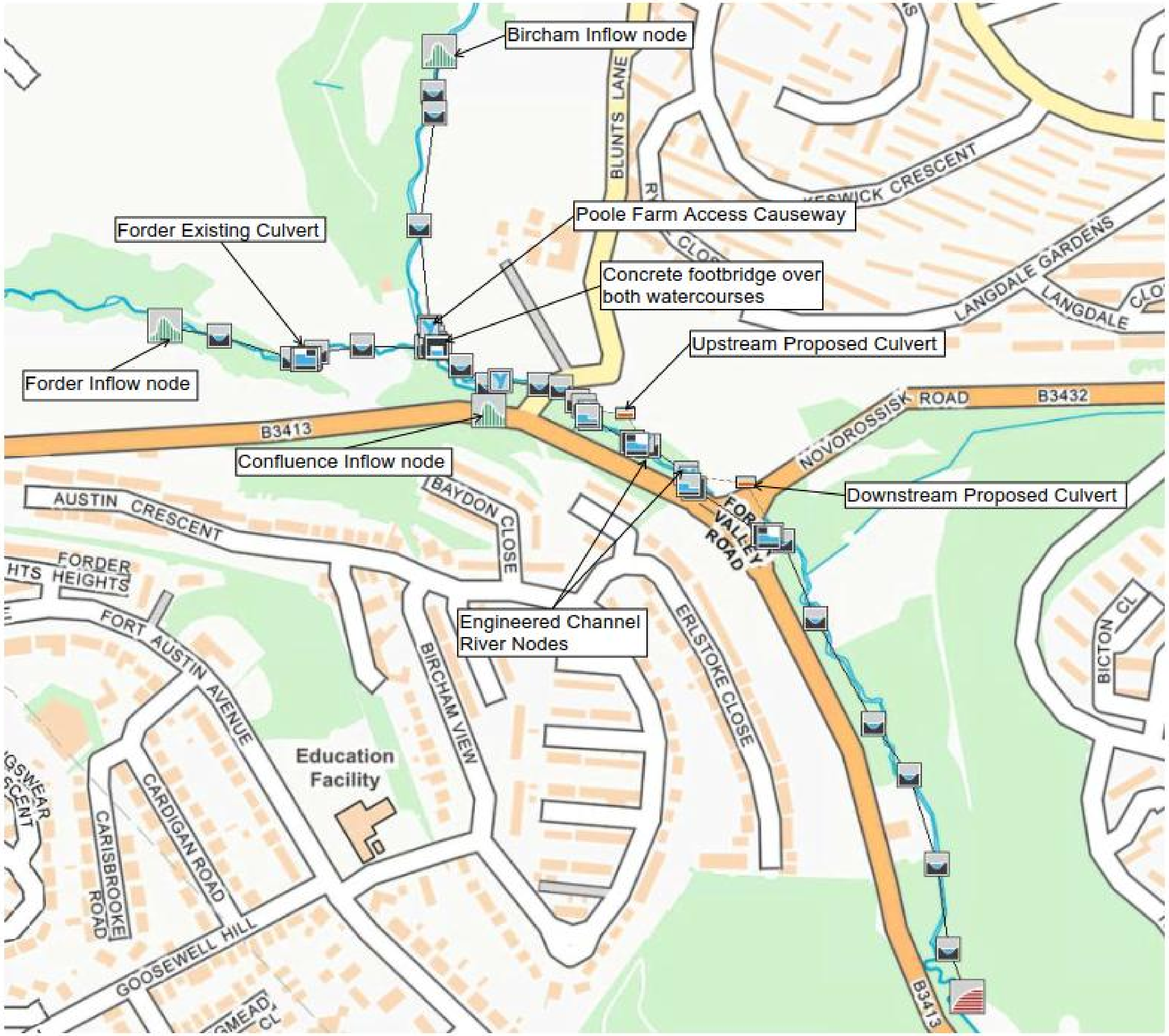
Appendix C. Simulation Run List

Model Ref.	Scenarios Topo	Reach	Flood Event Return Period	Build No.	ISIS Event file (.IEF)	ISIS file (.DAT)	Result Files	ISIS Event Data
Baseline Scenario								
FVLR	BASE	-	0005_C00	020	FVLR_BASE_0005_C00_020.ief	FVLR_BASE_020.dat	FVLR_BASE_0005_C00_020	FVLR_BASE_0005_C00
FVLR	BASE	-	0025_C00	020	FVLR_BASE_0025_C00_020.ief	FVLR_BASE_020.dat	FVLR_BASE_0025_C00_020	FVLR_BASE_0025_C00
FVLR	BASE	-	0050_C00	020	FVLR_BASE_0050_C00_020.ief	FVLR_BASE_020.dat	FVLR_BASE_0050_C00_020	FVLR_BASE_0050_C00
FVLR	BASE	-	0100_C00	020	FVLR_BASE_0100_C00_020.ief	FVLR_BASE_020.dat	FVLR_BASE_0100_C00_020	FVLR_BASE_0100_C00
FVLR	BASE	-	0200_C00	020	FVLR_BASE_0200_C00_020.ief	FVLR_BASE_020.dat	FVLR_BASE_0200_C00_020	FVLR_BASE_0200_C00
FVLR	BASE	-	0100_C40	020	FVLR_BASE_0100_C40_020.ief	FVLR_BASE_020.dat	FVLR_BASE_0100_C40_020	FVLR_BASE_0100_C40
FVLR	BASE	-	0100_C85	020	FVLR_BASE_0100_C85_020.ief	FVLR_BASE_020.dat	FVLR_BASE_0100_C85_020	FVLR_BASE_0100_C85
Proposed Scenario								
FVLR	PROP	-	0005_C00	020	FVLR_PROP_0005_C00_020.ief	FVLR_PROP_020.dat	FVLR_PROP_0005_C00_020	FVLR_PROP_0005_C00
FVLR	PROP	-	0025_C00	020	FVLR_PROP_0025_C00_020.ief	FVLR_PROP_020.dat	FVLR_PROP_0025_C00_020	FVLR_PROP_0025_C00
FVLR	PROP	-	0050_C00	020	FVLR_PROP_0050_C00_020.ief	FVLR_PROP_020.dat	FVLR_PROP_0050_C00_020	FVLR_PROP_0050_C00
FVLR	PROP	-	0100_C00	020	FVLR_PROP_0100_C00_020.ief	FVLR_PROP_020.dat	FVLR_PROP_0100_C00_020	FVLR_PROP_0100_C00
FVLR	PROP	-	0200_C00	020	FVLR_PROP_0200_C00_020.ief	FVLR_PROP_020.dat	FVLR_PROP_0200_C00_020	FVLR_PROP_0200_C00
FVLR	PROP	-	0100_C40	020	FVLR_PROP_0100_C40_020.ief	FVLR_PROP_020.dat	FVLR_PROP_0100_C40_020	FVLR_PROP_0100_C40
FVLR	PROP	-	0100_C85	020	FVLR_PROP_0100_C85_020.ief	FVLR_PROP_020.dat	FVLR_PROP_0100_C85_020	FVLR_PROP_0100_C85
Residual Risk and Sensitivity Scenarios								
FVLR	BLOC	-	0100_C40	001	FVLR_BLOC_0100_C40_001.ief	FVLR_BLOC_001.dat	FVLR_BLOC_0100_C40_001	FVLR_BLOC_0100_C40
FVLR	BLOC	-	0100_C40	002	FVLR_BLOC_0100_C40_002.ief	FVLR_BLOC_002.dat	FVLR_BLOC_0100_C40_002	FVLR_BLOC_0100_C40
FVLR	BLOC	-	0100_C40	003	FVLR_BLOC_0100_C40_003.ief	FVLR_BLOC_003.dat	FVLR_BLOC_0100_C40_003	FVLR_BLOC_0100_C40
FVLR	BRUH	-	0100_C40	001	FVLR_BRUH_0100_C40_001.ief	FVLR_BRUH_001.dat	FVLR_BRUH_0100_C40_001	FVLR_BRUH_0100_C40
FVLR	BRUH	-	0100_C40	002	FVLR_BRUH_0100_C40_002.ief	FVLR_BRUH_002.dat	FVLR_BRUH_0100_C40_002	FVLR_BRUH_0100_C40
FVLR	PRUH	-	0100_C40	001	FVLR_PRUH_0100_C40_001.ief	FVLR_PRUH_001.dat	FVLR_PRUH_0100_C40_001	FVLR_PRUH_0100_C40
FVLR	PRUH	-	0100_C40	002	FVLR_PRUH_0100_C40_002.ief	FVLR_PRUH_002.dat	FVLR_PRUH_0100_C40_002	FVLR_PRUH_0100_C40
FVLR	SLOP	-	0100_C40	001	FVLR_SLOP_0100_C40_001.ief	FVLR_SLOP_001.dat	FVLR_SLOP_0100_C40_001	FVLR_SLOP_0100_C40
FVLR	SLOP	-	0100_C40	002	FVLR_SLOP_0100_C40_002.ief	FVLR_SLOP_002.dat	FVLR_SLOP_0100_C40_002	FVLR_SLOP_0100_C40
FVLR	SLOP	-	0100_C40	003	FVLR_SLOP_0100_C40_003.ief	FVLR_SLOP_003.dat	FVLR_SLOP_0100_C40_003	FVLR_SLOP_0100_C40
FVLR	SLOP	-	0100_C40	004	FVLR_SLOP_0100_C40_004.ief	FVLR_SLOP_004.dat	FVLR_SLOP_0100_C40_004	FVLR_SLOP_0100_C40

Baseline Model (BASE)



Proposed Model (PROP)



Appendix F. Model Results

Peak Modelled Flow (m^3/s)

Location	Node	1 in 5		1 in 25		1 in 50		1 in 100		1 in 200		1 in 100 +40%		1 in 100 +85%	
		BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP
Bircham Stream Reach															
Upstream end of Reach	Bir119	2.80	2.80	4.14	4.14	4.89	4.89	5.80	5.80	6.91	6.91	8.12	8.12	10.73	10.73
	Bir137	2.83	2.82	4.16	4.16	4.91	4.92	5.85	5.90	6.93	7.05	8.14	8.21	10.77	10.81
	Bir245	2.81	2.81	4.15	4.14	4.90	4.90	5.80	5.81	6.92	6.92	8.12	8.12	10.75	10.76
Upstream of Poole Farm Causeway	Bir343U	2.80	2.80	4.14	4.14	4.89	4.89	5.80	5.80	6.90	6.90	8.11	8.12	10.73	10.72
Downstream of Poole Farm Causeway	Bir343D	2.80	2.80	4.14	4.14	4.89	4.89	5.80	5.80	6.90	6.90	8.11	8.12	10.73	10.72
Connection point for spill from the Forder Stream	Bir351	2.81	2.80	4.14	4.14	4.89	4.89	5.80	5.80	6.90	6.90	8.11	8.12	10.73	10.72
Downstream extent of Reach (connection point to Forder)	Bir357	2.81	2.80	4.14	4.14	4.89	4.89	5.80	5.80	6.84	6.83	7.93	7.93	10.20	10.19
Forder Stream Reach															
Upstream end of Forder Stream reach	For113	1.34	1.34	1.97	1.97	2.33	2.33	2.77	2.77	3.29	3.29	3.87	3.87	5.12	5.11
Upstream of existing Forder Stream Culvert	For210	1.33	1.33	1.97	1.97	2.33	2.33	2.76	2.76	3.29	3.29	3.86	3.87	5.11	5.11
Downstream of existing Forder Stream Culvert	For217	1.33	1.33	1.97	1.97	2.33	2.33	2.76	2.76	3.29	3.29	3.86	3.87	5.11	5.11
Connection point for spill from Bircham stream	For351	1.33	1.33	1.97	1.97	2.33	2.33	2.76	2.76	3.29	3.28	3.86	3.86	5.11	5.11
Upstream of model Reach Junction	For357U	1.33	1.33	1.97	1.97	2.32	2.33	2.76	2.76	3.34	3.34	4.04	4.04	5.62	5.62
Downstream of model Reach Junction	For357D	4.13	4.13	6.08	6.08	7.18	7.18	8.51	8.51	10.11	10.11	11.92	11.91	15.75	15.76
Upstream of concrete footbridge	For361U	4.13	4.13	6.08	6.08	7.18	7.18	8.51	8.51	10.11	10.11	11.92	11.91	15.74	15.76
Downstream of concrete footbridge	For361D	4.13	4.13	6.08	6.08	7.18	7.18	8.51	8.51	10.11	10.11	11.92	11.91	15.74	15.76
Upstream of stream actual confluence and third inflow point	For420U	4.13	4.13	6.08	6.09	7.18	7.18	8.51	8.51	10.11	10.11	11.92	11.91	15.75	15.75
Downstream of stream actual confluence and third inflow point	For420D	4.84	4.84	7.13	7.14	8.43	8.42	9.98	9.98	11.86	11.87	13.98	13.97	18.47	18.48
Upstream end of Blunts Lane Culvert	For454	4.84	4.84	7.14	7.15	8.43	8.42	9.99	9.98	11.87	11.86	13.99	13.97	18.48	18.47
Downstream end of Blunts Lane Culvert	For476	4.84	4.84	7.14	7.14	8.43	8.42	9.99	9.98	11.87	11.86	13.99	13.97	18.48	18.47
River section downstream of Last structure in both models	For804	4.84	4.84	7.08	7.14	8.27	8.42	9.97	9.98	11.87	11.86	13.98	13.97	18.48	18.47
	For924	4.84	4.83	7.08	7.13	8.27	8.41	9.96	9.97	11.86	11.85	13.96	13.95	18.45	18.44
	For983	4.83	4.83	7.08	7.12	8.27	8.40	9.96	9.96	11.85	11.84	13.95	13.94	18.44	18.42
	For1065	4.83	4.83	7.08	7.12	8.26	8.40	9.96	9.96	11.85	11.84	13.95	13.94	18.44	18.42
Downstream extent of model	For1156	4.83	4.83	7.08	7.12	8.26	8.40	9.95	9.96	11.85	11.84	13.95	13.94	18.44	18.41

Peak Modelled Water Level (mAOD)

Location	Node	Bed lvl (mAOD)	1 in 5		1 in 25		1 in 50		1 in 100		1 in 200		1 in 100 +40%		1 in 100 +85%	
			BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP	BASE	PROP
Bircham Stream Reach																
Upstream end of Reach	Bir119	32.83	33.31	33.31	33.40	33.40	33.44	33.44	33.48	33.49	33.52	33.52	33.58	33.58	33.66	33.66
	Bir137	32.12	32.58	32.58	32.67	32.67	32.71	32.71	32.76	32.76	32.80	32.80	32.85	32.85	32.95	32.94
	Bir245	27.33	27.99	27.99	28.11	28.11	28.17	28.17	28.23	28.23	28.30	28.30	28.37	28.37	28.49	28.50
Upstream of Poole Farm Causeway	Bir343U	23.55	24.73	24.73	24.82	24.82	24.87	24.86	24.91	24.91	24.97	24.97	25.02	25.02	25.12	25.12
Downstream of Poole Farm Causeway	Bir343D	23.55	24.16	24.16	24.27	24.27	24.32	24.32	24.36	24.36	24.41	24.41	24.45	24.45	24.60	24.60
Connection point for spill from the Forder Stream	Bir351	23.07	23.91	23.91	24.05	24.05	24.12	24.12	24.19	24.19	24.26	24.26	24.33	24.33	24.44	24.44
Downstream extent of Reach (connection point to Forder)	Bir357	22.99	23.80	23.80	23.93	23.93	23.98	23.98	24.04	24.04	24.10	24.10	24.15	24.15	24.26	24.26
Forder Stream Reach																
Upstream end of Forder Stream reach	For113	29.32	29.73	29.73	29.81	29.81	29.86	29.86	29.90	29.90	29.95	29.95	29.99	29.99	30.08	30.08
Upstream of existing Forder Stream Culvert	For210	26.81	28.06	28.06	28.21	28.21	28.25	28.25	28.28	28.28	28.32	28.32	28.36	28.36	28.43	28.43
Downstream of existing Forder Stream Culvert	For217	26.07	26.74	26.74	26.86	26.86	26.92	26.92	26.97	26.97	27.03	27.03	27.09	27.09	27.18	27.18
Connection point for spill from Bircham stream	For351	23.33	23.92	23.92	23.99	23.99	24.04	24.04	24.09	24.09	24.15	24.15	24.20	24.20	24.31	24.31
Upstream of model Reach Junction	For357U	23.3	23.82	23.82	23.94	23.94	23.99	23.99	24.05	24.05	24.11	24.11	24.16	24.16	24.27	24.27
Downstream of model Reach Junction	For357D	23.3	23.80	23.80	23.93	23.93	23.98	23.98	24.04	24.04	24.10	24.10	24.15	24.15	24.26	24.26
Upstream of concrete footbridge	For361U	22.98	23.69	23.69	23.81	23.81	23.87	23.87	23.92	23.92	23.99	23.99	24.05	24.05	24.15	24.15
Downstream of concrete footbridge	For361D	22.98	23.65	23.65	23.76	23.76	23.81	23.81	23.86	23.86	23.92	23.92	23.98	23.98	24.08	24.08
Upstream of stream actual confluence and third inflow point	For420U	21.12	22.06	22.00	22.24	22.17	22.32	22.26	22.41	22.34	22.50	22.44	22.59	22.53	22.76	22.69
Downstream of stream actual confluence and third inflow point	For420D	21.12	22.06	22.00	22.24	22.17	22.32	22.26	22.41	22.34	22.50	22.44	22.59	22.53	22.76	22.69
Upstream end of Blunts Lane Culvert	For454	19.91	21.86	21.21	22.01	21.63	22.09	21.79	22.18	21.86	22.27	21.90	22.36	21.97	22.51	22.15
Downstream end of Blunts Lane Culvert	For476	19.9	20.87	20.57	21.10	20.80	21.22	20.92	21.34	21.05	21.47	21.20	21.62	21.36	21.88	21.68
River section downstream of Last structure in both models	For804	13.89	14.62	14.66	14.74	14.80	14.79	14.86	14.86	14.94	14.93	15.02	15.00	15.10	15.13	15.25
	For924	11.48	12.62	12.63	12.80	12.81	12.88	12.90	13.00	13.00	13.11	13.11	13.22	13.23	13.45	13.46
	For983	10.82	12.15	12.15	12.40	12.41	12.51	12.53	12.65	12.65	12.77	12.77	12.91	12.91	13.15	13.15
	For1065	9.9	11.07	11.07	11.28	11.28	11.36	11.37	11.45	11.45	11.55	11.55	11.65	11.65	11.83	11.83
Downstream extent of model	For1156	8.88	9.98	9.98	10.13	10.13	10.18	10.18	10.24	10.24	10.31	10.31	10.38	10.38	10.53	10.53