

File Note

Project title	Victoria North Infrastructure Works
Job number	282022
File reference	4-05-02
cc	
Prepared by	Emily Stoddart
Date	6 October 2025
Subject	St Catherine's Wood Riverside Path - Flood Risk Impact Note – Rev 07

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1. Introduction

This note has been prepared to form an assessment of the proposals for the Phase 2 extent of the Victoria North site, in relation to flood risk. This assessment aims to seek EA acceptance of the current proposals in relation to flood risk by presenting a comparison against the proposals previously consented as part of Planning Application reference 133143/VO/2022. The Phase 2 boundary is shown in Figure 1 and includes two riverside footpaths and associated bank re-profiling.

This note should be read with reference to the HIF works Flood Risk Assessment (FRA) **VNIF-ARP-ZZ-YYY-RP-CD-0002**, and addresses points raised by the EA in correspondence *ENVPAC.1.GMC.00580 - VN HIF 24-25 - EA Preliminary Review - Riverside Walkway & Embankment Technical Note - Issued 11.07.2024* and subsequent engagement.

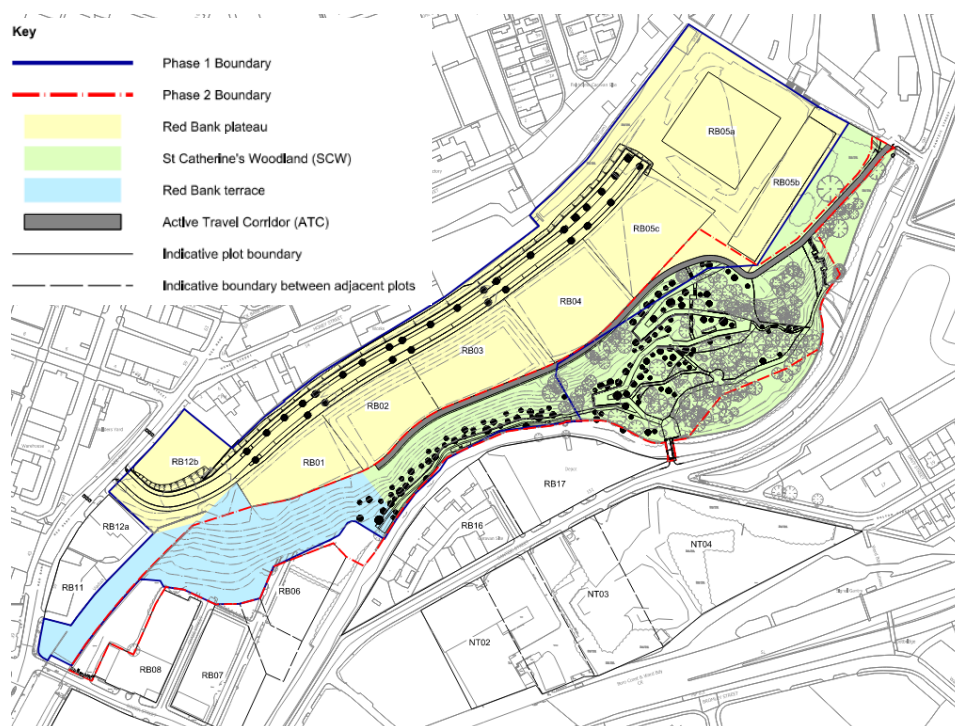


Figure 1 Phase Boundaries

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The Phase 2 boundary includes two key areas of the riparian corridor:

1. Proposed Riverside Footpath up to St Catherine's Wood Bridge (also referred to as Dalton Bridge), see Figure 2. This section of footpath is referred to as the 'Riverside Footpath' for the purpose of this note.
2. Footpath to Environment Agency monitoring station, adjacent to Collyhurst Weir, referred to as the 'EA Footpath', see Figure 3.

Outside of these two zones, the riparian corridor is proposed to remain in situ to the pre-development levels, therefore there will be no impact on flood risk resulting from development outside of these two areas of interest.

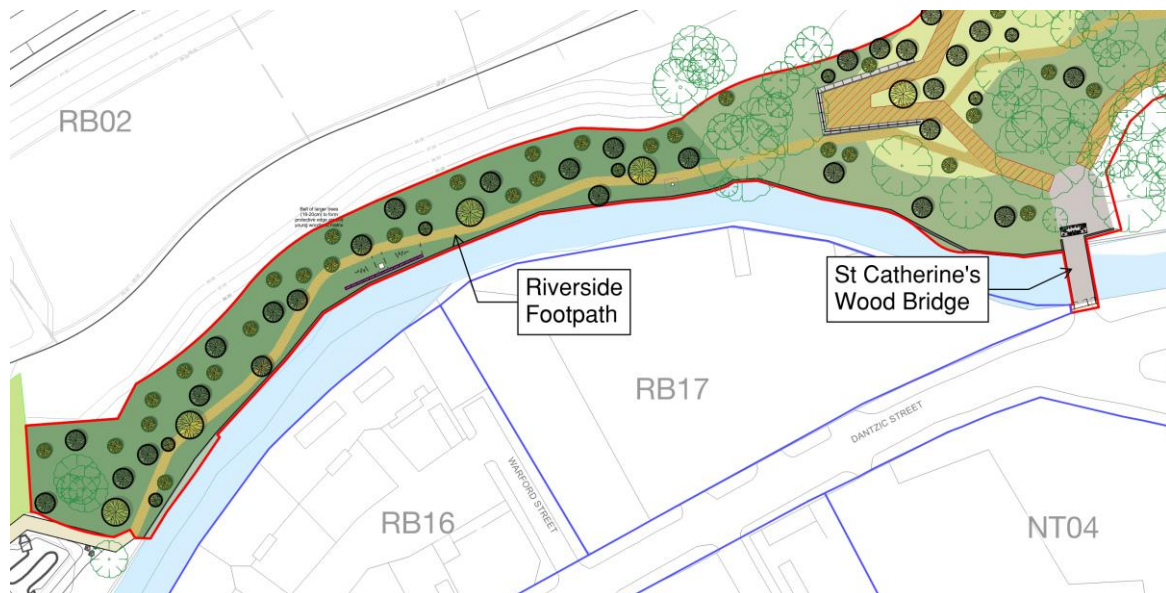


Figure 2 Proposed layout of Riverside Footpath up to St Catherine's Wood Bridge

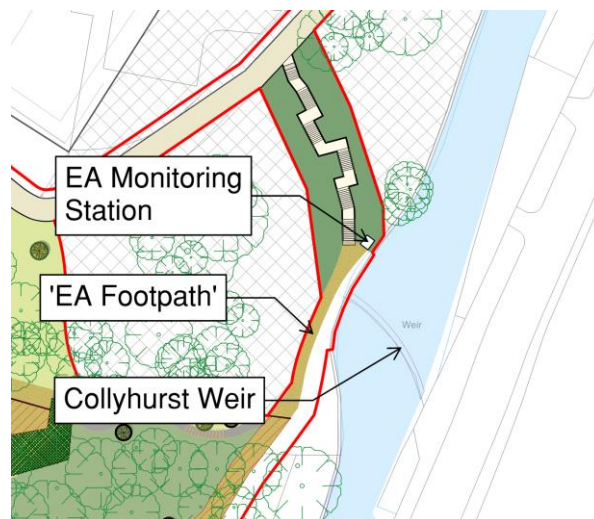


Figure 3 Proposed Layout of 'EA Footpath'

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The purpose of this note is to demonstrate the following:

1. The Phase 2 proposals, including the proposed footpaths and overall re-profiling strategy of the river embankment are suitable in relation to the pre and post-development flood levels within the river.
2. The Phase 2 proposals, including the proposed footpaths and overall re-profiling strategy of the river embankment have no adverse impact on flood risk elsewhere and are in line with the approved principles within the HIF FRA (VNIF-ARP-ZZ-YYY-RP-CD-0002) which was submitted as part of planning application 133143/VO/2022.
3. The Phase 2 proposals, including the proposed footpaths and overall re-profiling strategy of the river embankment are suitable in principle for locating within Flood Zone 3.

1.1 Timeline

Table 1 shows key dates related to previous surveys, design and assessments of flood risk for the riverside footpath, the table provides a reference for the various site conditions and designs discussed within this note.

Table 1 Timeline of key project milestones in relation to the riverside footpath

	Project Milestone	Date
01	Sitewide Topographic survey – referred to as ‘ <i>original condition</i> ’	September 2021
02	Sitewide infrastructure design including riverside footpath with terracing based on Sep 2021 topographic survey and intent for river naturalisation as part of Victoria North River Works scheme – referred to as ‘ <i>consented design</i> ’	November 2021
03	FRA VNIF-ARP-ZZ-YYY-RP-CD-0002 submitted and approved as part of outline planning application 133143/VO/2022 based on ‘ <i>consented design</i> ’	19 April 2022
04	River Works scheme was de-scoped and extent of terracing/naturalisation of the riparian corridor was reduced. The ‘ <i>interim design</i> ’ was developed which included the riverside footpath with no amendments to the ‘ <i>original condition</i> ’ levels.	February 2023
05	WSP flood modelling with representation of ‘ Application 4’ and ‘ Application 5’ plot levels and building extents – these are development plots adjacent to the River Irk as shown in Figure 17.	23 June 2023
06	Fill material above river wall removed during invasive species management. Drone survey undertaken showing reduced levels above the river wall compared to the ‘ <i>original condition</i> ’ – referred to as ‘ <i>existing condition</i> ’	March 2024
07	3D assessment and development of updated footpath design options to account for the ‘ <i>existing condition</i> ’ – referred to as ‘ <i>proposed design</i> ’	Commenced April 2024
08	Workshopping with Joint Venture (JV), i.e. MCC/FEC including options sifting and option selection process for the ‘ <i>proposed design</i> ’	01 May 2024 and 26 June 2024

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	Project Milestone	Date
09	First iteration of Flood Risk Impact Note issued to the Environment Agency (EA) providing justification for the ' <i>proposed design</i> ' with relation to flood risk and comments received	July 2024
10	Development of detailed design for footpath incorporating EA comments, confirmation of change to Phase 2 Planning Boundary, re-engagement with EA	May - July 2025
11	Further EA engagement to address specific concerns related to flow paths and the St Catherine's Wood Bridge gate design	September 2025

2. Summary of Proposals

2.1 Original Condition, Interim Design and Existing Condition

As part of the '*consented design*', submitted and consented under outline planning (reference 133143/VO/2022), proposals were developed for new footpaths and terracing along the north bank of the River Irk, these proposals included terracing to the north bank of the River Irk and removal of the existing river wall along part of its length as part of river restoration efforts. After the River Works were de-scoped, the '*interim design*' was developed which instead tied the footpath into the '*original condition*' levels as shown in Figure 4.

Following recent invasive species management works, the site team have discovered that a layer of fill material was located above the existing river wall on the north bank of the River Irk. This material was up to 2m deep in areas and it is thought to have deposited via slippage at the toe of the steep made ground slope to the north of the river. A sketch of the '*original condition*' of the river wall and embankment is shown in Figure 4. The fill material has now been removed and the bank has been levelled with the existing river wall to enable the treatment of invasive species, Figure 5 shows a photo of the '*existing condition*' above the river wall for the extent of the Riverside Footpath.

Given the current '*existing condition*' is different to what was understood originally, an alternative design for the arrangement of the footpaths have been developed to prevent the need to build levels back up to the '*original condition*' levels or to increase loading on the river wall.

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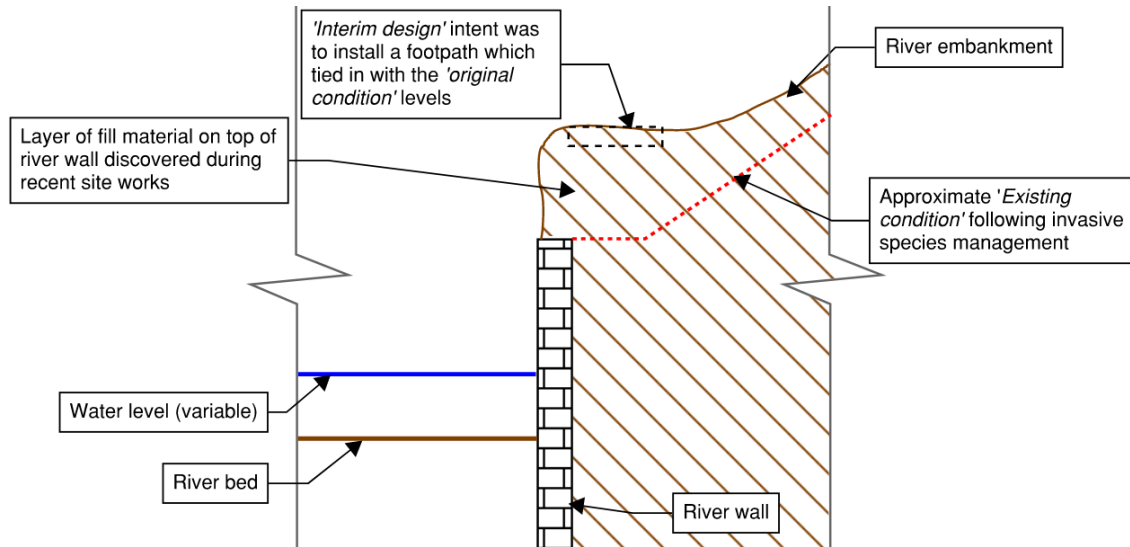


Figure 4 Indicative section showing *original condition* of the riverside footpath extent and river embankment



Figure 5 Photo showing *existing condition* of the river wall and embankment at the extents of the riverside footpath - facing downstream along the River Irk from the top of the river embankment

The ‘EA Footpath’ has also been reduced in level during invasive species management and interim site works, the ‘*existing condition*’ is shown in Figure 6. The intent is to maintain and formalise this footpath at the current ‘*existing condition*’ levels.

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Figure 6 Photo showing existing condition of the 'EA Footpath' with temporary balustrade installed during construction works

2.2 Proposed Design

2.2.1 Riverside Footpath

The preferred option for the revised '*proposed design*' of the riverside footpath is shown in Figure 7, and will involve permanently reducing the level of the proposed footpath from the '*original condition*' levels. The footpath will be set back from the existing river wall and a small embankment will be provided to the river's edge. A modular retaining structure is proposed behind the footpath as well as bank-reprofiling to tie in with the top of slope levels.

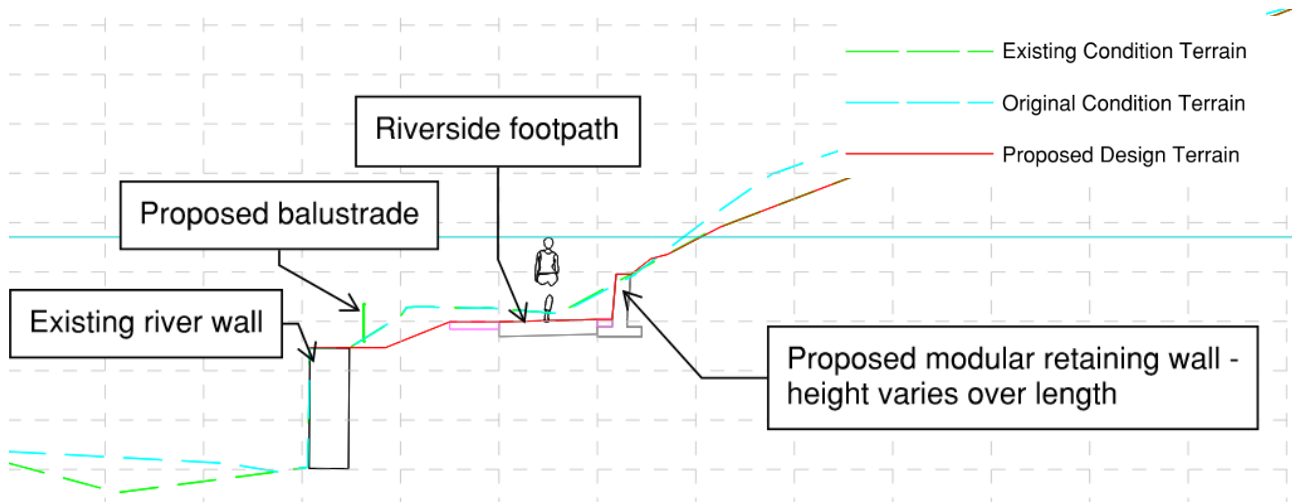


Figure 7 Sketch showing section through river wall and slope

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There are two existing United Utilities (UU) chambers within the extent of the riverside footpath. Engagement with UU has identified that access needs to be maintained to these chambers, and that the cover levels of the chambers must also be maintained. The design therefore includes two localised areas where the levels of the footpath are maintained closer to the 'original condition' levels. Detailed cross sections through the two UU chambers are given in VNIF-ARP-00-YYY-DR-CD-0070 and in Figure 8 and Figure 9.

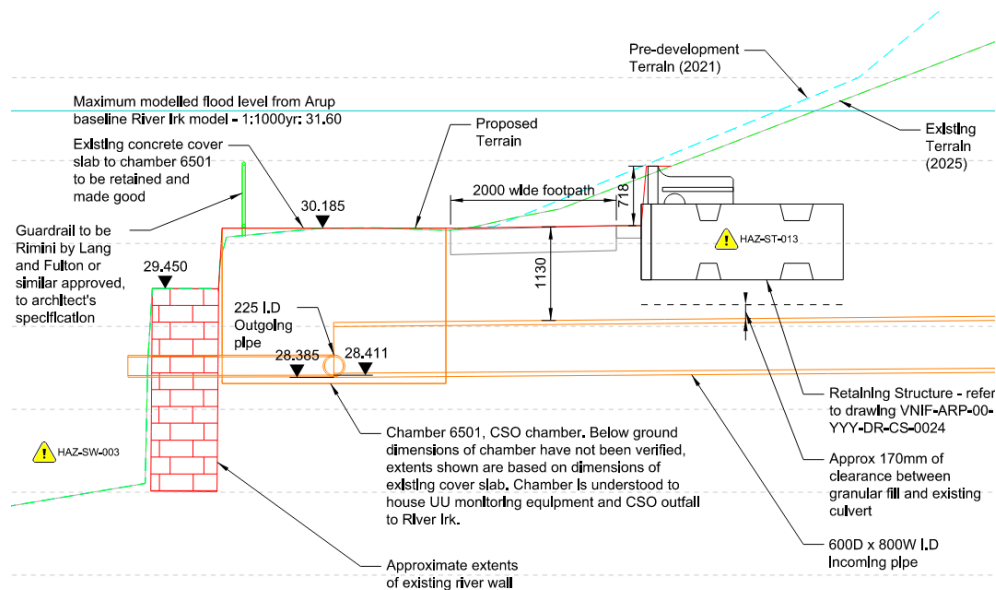


Figure 8 Section view of UU Chamber 6501 taken from VNIF-ARP-00-YYY-DR-CD-0070

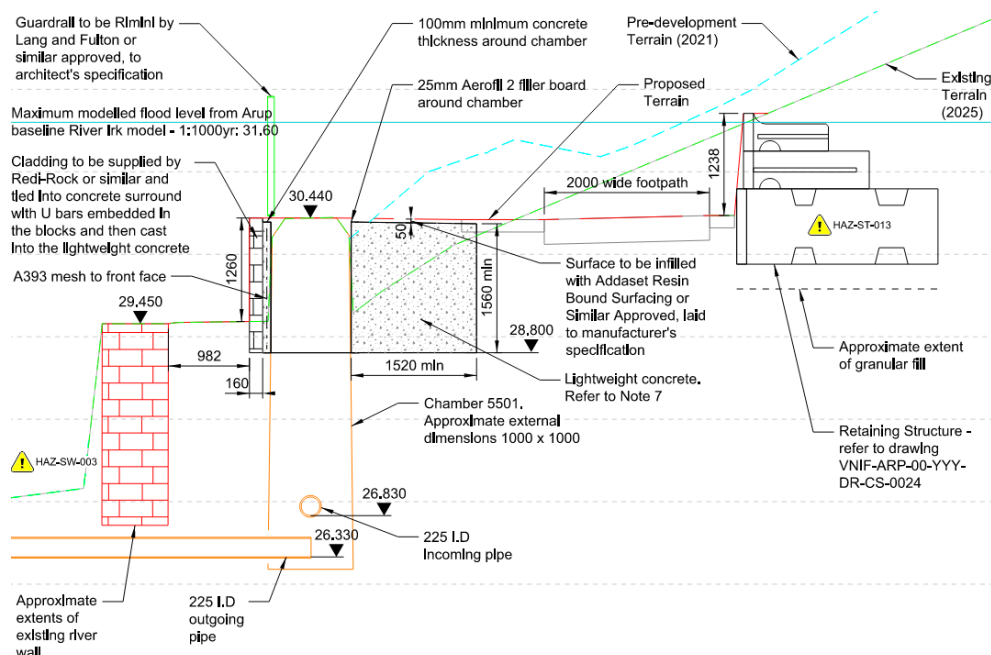


Figure 9 Section view of UU Chamber 5501 taken from VNIF-ARP-00-YYY-DR-CD-0070

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The proposed retaining wall structure to the rear of the footpath is to be a modular Redi-Rock wall or equivalent concrete retaining structure as agreed in principle through engagement with the EA. The proposed wall product is shown in Figure 10.



Figure 10 Example Image of Proposed Modular Retaining Wall Product to Rear of Riverside Footpath – Redi-Rock or Similar Approved

2.2.2 EA Footpath

The EA path is proposed to be maintained as per the current '*existing condition*', which provides a reduction in level compared to the '*original condition*', due to recent site clearance and invasive species management. In proximity to the EA path, a buried utilities crossing has been installed by Bam under a Flood Risk Activity Permit as part of the utilities connections strategy for the site, and the river wall has been reinstated as per existing.

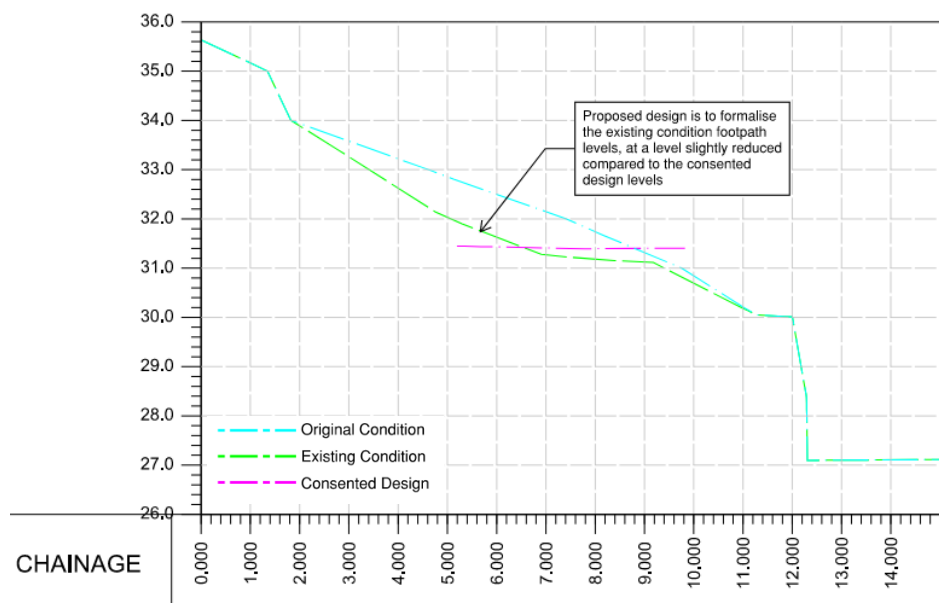


Figure 11 Cross Section of EA Footpath showing Original Condition, Existing Condition and Consented Design

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2.2.3 St Catherine's Wood Bridge

The proposals at St Catherine's Wood Bridge (also known as Dalton Bridge) include the following:

- Structural repairs to the underside of the bridge (no change to current bridge dimensions/sizing)
- Re-surfacing of the bridge deck with granite sett paving
- Replacement of the parapet to each side of the bridge with like-for-like open railings
- Replacement of the existing vehicle barrier with a new gate to the South end of the bridge
- Addition of HVM sliding bollard system to the North end of the bridge

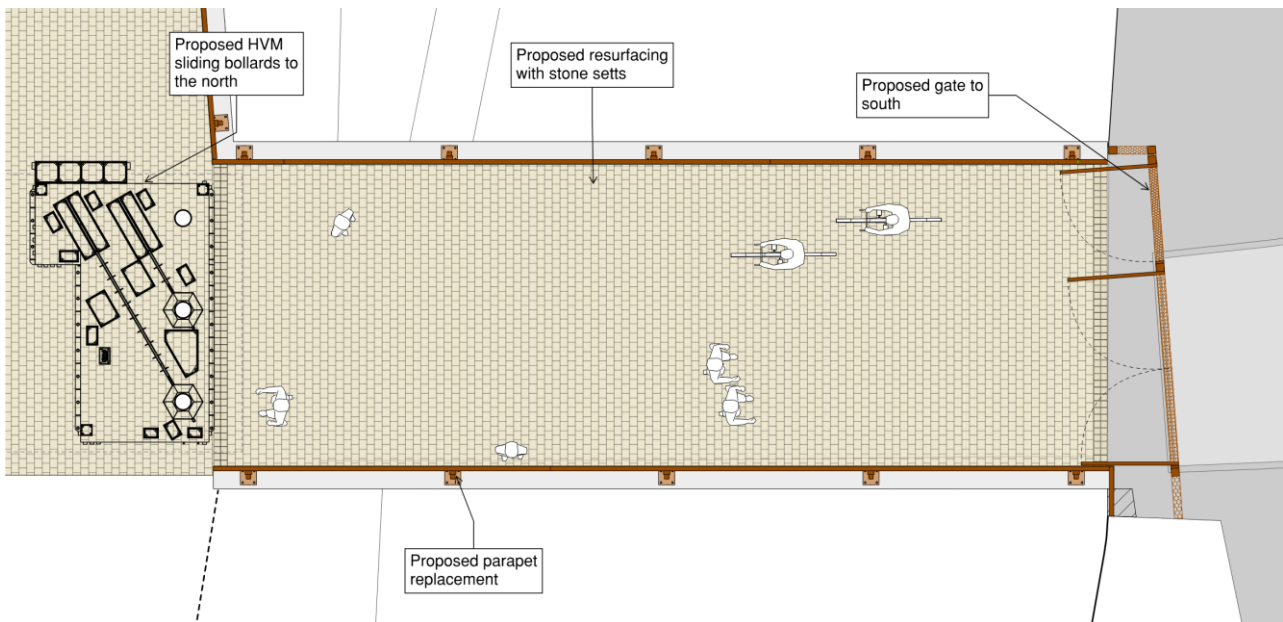


Figure 12 Plan showing proposals at St Catherine's Wood Bridge

Refer to Appendix C for drawings detailing the existing condition and proposed design for the bridge.

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3. Existing and Post-Development Flood Risk

3.1 Existing Flood Risk

This section summarises the existing flood risk based on the Environment Agency Flood Zone data which was assessed under the FRA for the scheme (VNIF-ARP-ZZ-YYY-RP-CD-0002).

Figure 13 shows that the riverside footpath sits within Flood Zone 3 (High Risk), meaning it has a 1% or greater probability of flooding from rivers in any given year. A section at the eastern end of the footpath within St Catherine's Wood sits in both Flood Zone 2 (Medium Risk with between 0.1% and 1% probability of flooding in any given year) and Flood Zone 1 (Low Risk with less than 0.1% probability of flooding in any given year). The anticipated impact of the 'proposed design' on flood risk is discussed in Section 4.

The EA footpath is immediately adjacent to Collyhurst Weir, which is shown within Flood Zone 1 based on the EA Flood Zone data (see Figure 14). However, this appears to be due to model triangulation of the EA flood data as the northern edge of the footpath immediately adjacent and at an equivalent level is within Flood Zone 3. Therefore, for the purposes of this note, the EA footpath is considered to be within Flood Zone 3 under the 'original condition'.

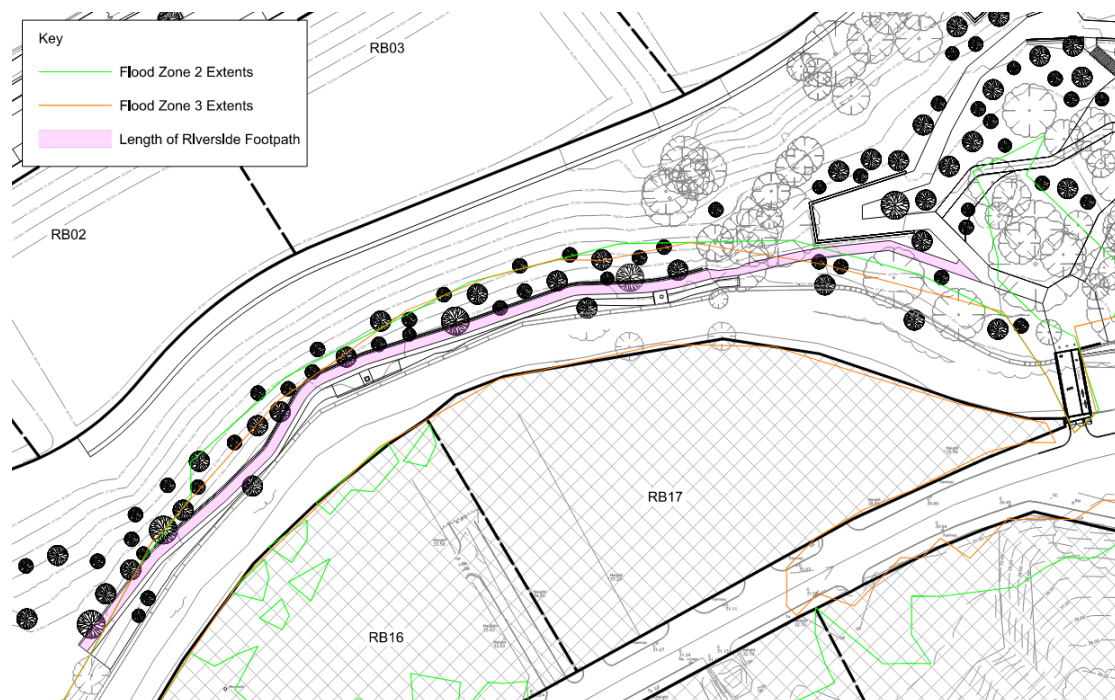


Figure 13 Existing Flood Zone extents for the riverside footpath (Flood Zone data received from EA on 12 March 2024)

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Figure 14 Existing flood zone extents for the EA footpath (Flood Zone data received from EA on 12 March 2024)

3.1.1 Existing Flow Routes (pre development ‘existing condition’)

Previous Arup modelling for the baseline condition of the site was undertaken in 2022 in collaboration with the EA, see hydraulic model technical note in Appendix D for details (this model will hereafter be referred to as the ‘2022 baseline’). The outputs of this model have been reviewed in relation to the flow paths which were observed in proximity to infrastructure proposed within Phase 2 of the development.

Collyhurst Road

Figure 15 shows the flow vectors at a timestep within the 100yr+CC event from the 2022 baseline model along Collyhurst Road. Out-of-channel flows are observed from the location of Collyhurst Weir, travelling south-west along Collyhurst Road. Flows then partially re-enter the channel along a 26m stretch of the left bank of the River Irk, with some flows continuing along Dantzic Street.

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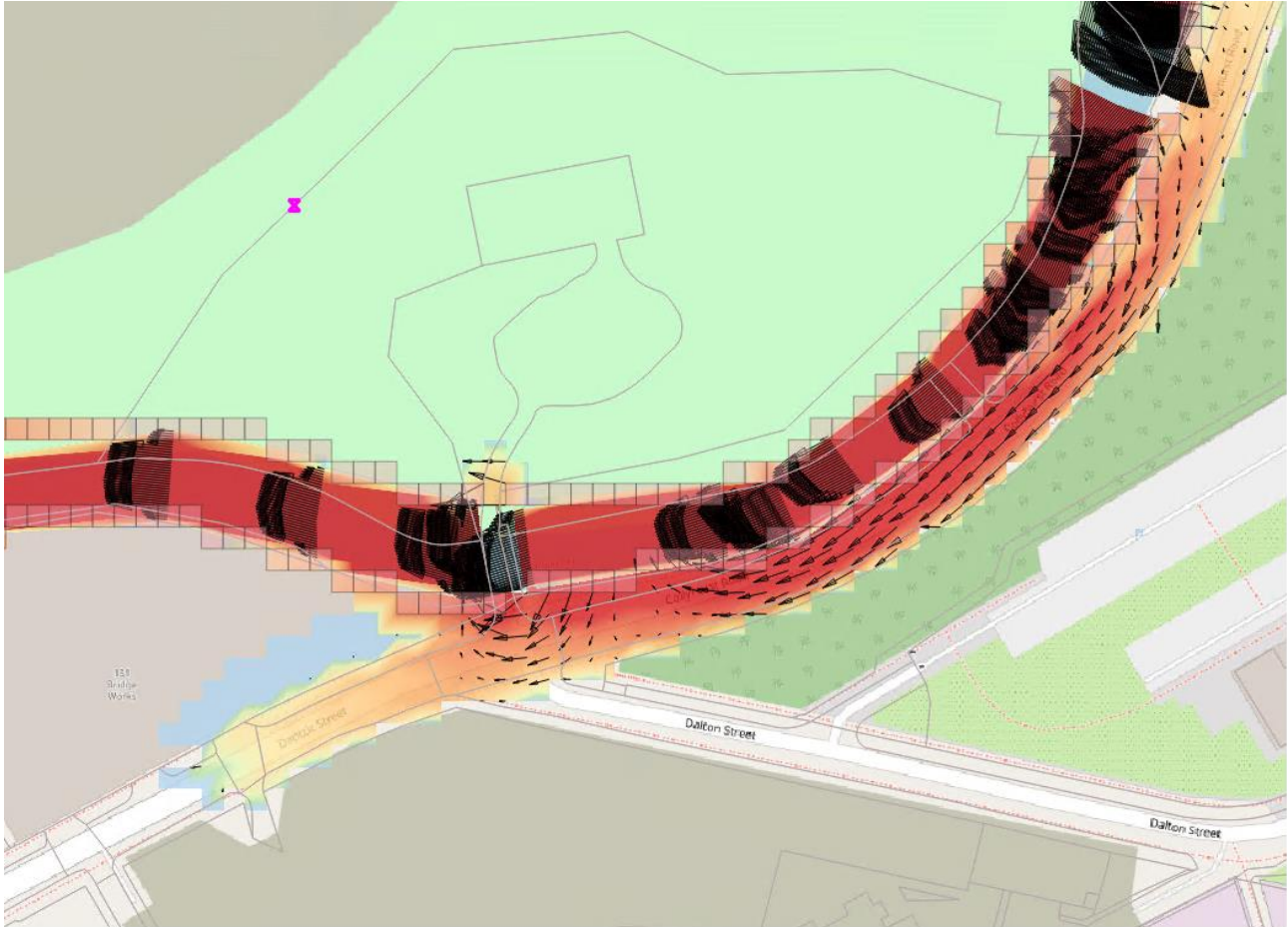


Figure 15 Flow vectors observed on Collyhurst Road during the 100yr+CC event in the 2022 baseline model

Adjacent to riverside footpath area/Dantzic Street

Figure 16 shows the flow vectors at a timestep within the 100yr+CC event from the 2022 baseline model in the vicinity of the proposed riverside footpath. Incoming overland flows are shown coming from the east originating from the out-of-bank flow at Collyhurst Weir as shown in Figure 15. This shows under existing conditions, all in-channel flows at this location are contained within channel, and flows do not leave the channel adjacent to proposed riverside footpath.

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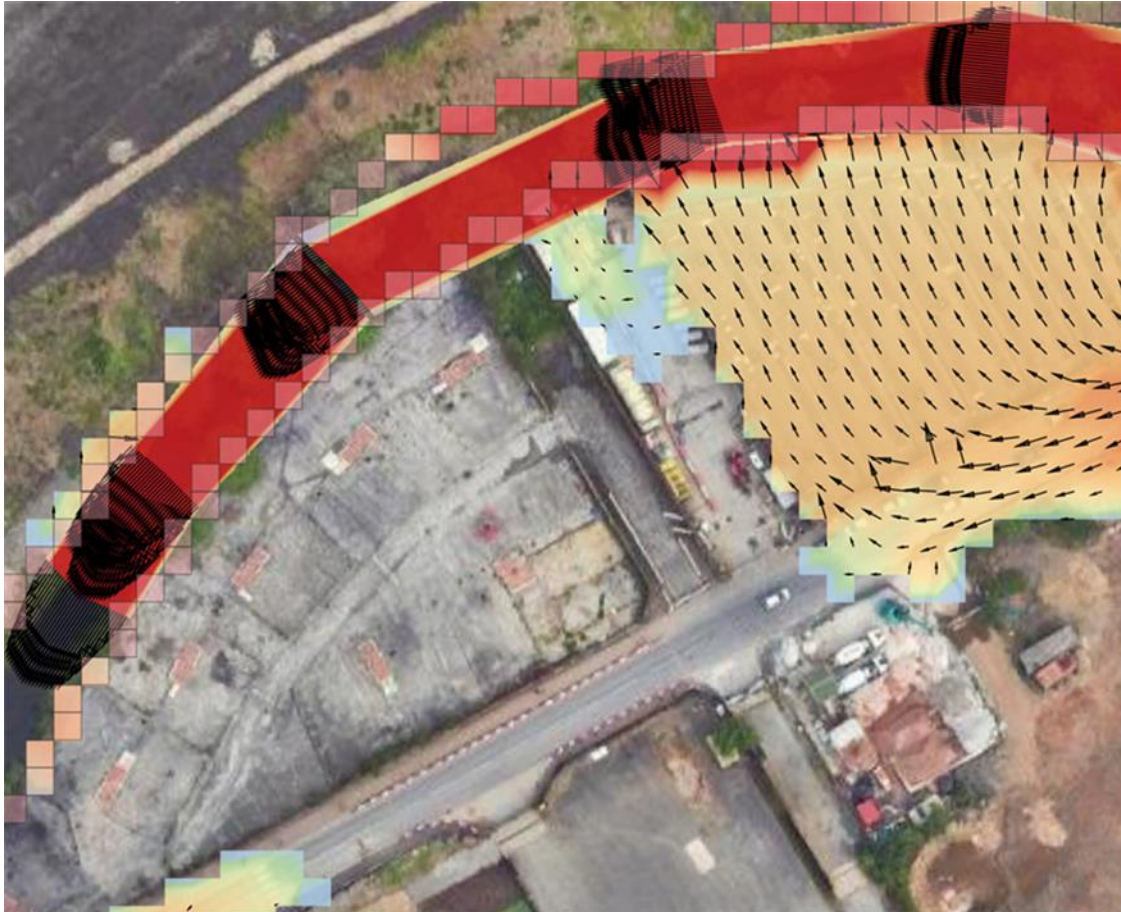


Figure 16 Flow vectors adjacent to Riverside Footpath during the 100yr+CC event in the 2022 baseline model

3.2 Post-Development Flood Risk

As part of the wider Victoria North development, flood modelling was undertaken by WSP on behalf of the developer, Far East Consortium (FEC), to determine the impacts of development on flood risk for 2 no. planning applications referred to as ‘Application 4’ and ‘Application 5’. The technical note with the subject ‘*FEC Red Bank Hydraulic Modelling*’ dated 23 June 2023 by WSP has been reviewed to assess the flood risk at the riverside footpath under the proposed scenario for both planning applications. Further data, including modelled 1D flood levels, has also been provided by WSP to inform this assessment.

The 2023 FEC model uses the original 2022 Arup baseline River Irk hydraulic model, which was developed as part of the HIF River Works, as the basis for further modelling. The FEC baseline differs from the Arup baseline as it includes a representation of the Victoria Riverside development (since consented and under construction) and a small amendment to represent the full channel width at the culvert inlet adjacent to the RB10 plot. A comparison between the FEC baseline and Arup baseline was undertaken by WSP which found that these updates had negligible impact on flood levels across the 2D domain (extents outside of main channel areas).

To determine the impacts of on-plot development on flood risk, ‘Application 4’ and Application 5’ models were developed by WSP. These models build on the FEC baseline by including

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representation of the proposed site levels and building footprints for the plots included in both applications. The plots modelled under each application are shown in Figure 17.



Figure 17 Plots modelled under 'Application 4' and 'Application 5' in the FEC flood model

The FEC models do not include representation of the HIF works as proposed, including bank re-profiling, which were modelled by Arup as part of the HIF FRA **VNIF-ARP-ZZ-YYY-RP-CD-0002**. Therefore, they represent the impacts on flood risk of the on-plot development only. More detail on the modelling undertaken as part of the HIF FRA is given in Section 4.

WSP found that the impact of the 'Application 5' plots on flood risk was negligible as these plots are mostly outside the baseline flood extents for all modelled events. The impact of the 'Application 4' plots on flood risk are shown in Figure 18 for the 1% AEP event + climate change. The WSP modelling showed that flood depths increase by > 0.1m within the channel adjacent to sections of the riverside footpath. Along other sections of the riverside footpath, and at the 'EA footpath', flood depths decrease by up to 0.1m. There is also an increase in flood extents to the south of the riverside footpath.



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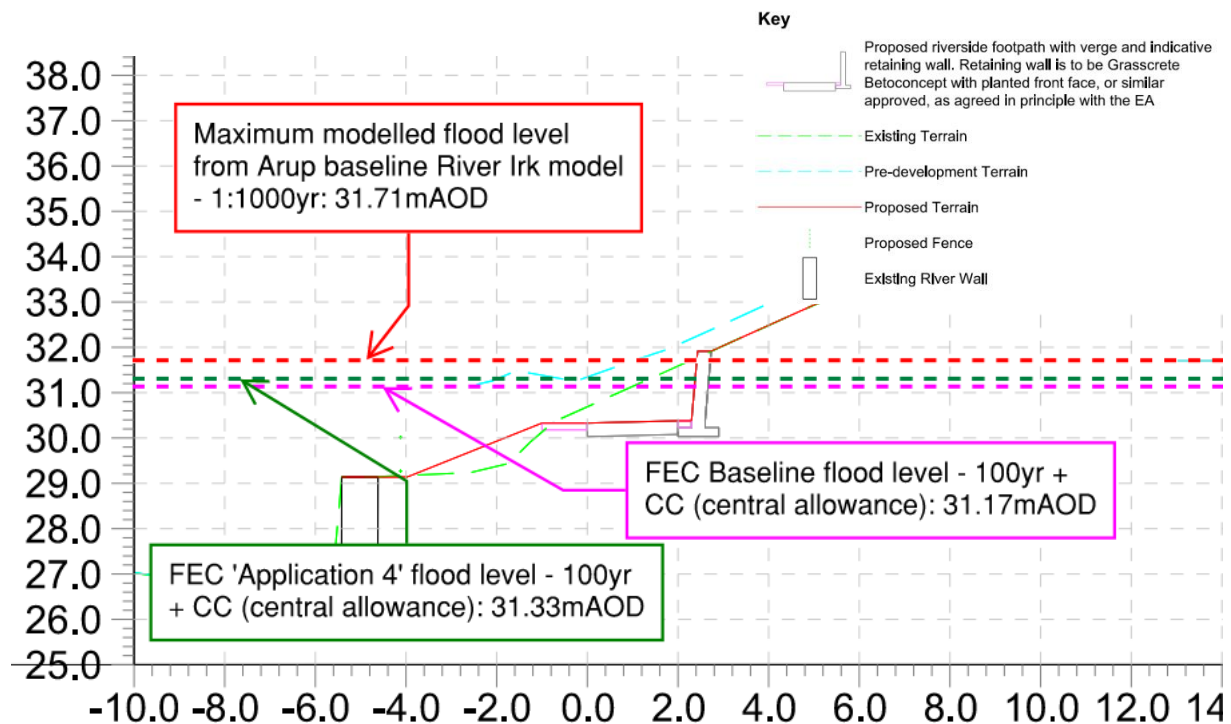


Figure 19 Modelled flood levels at Cross Section CH90 (IRK_RO1_1188A)

As the FEC model results show flood levels reducing along the extent of the 'EA Footpath', the pre-plot-development scenario is considered the critical condition across these extents.

This assessment has shown that the proposed footpaths are within Flood Zone 3, meaning it is below the pre-development and post-development flood level for the 1% AEP event. Therefore, the detailed design of the footpath and retaining wall will ensure that all features can withstand the hydraulic loading which can be expected during a flood event, and that the footpath is able to effectively drain after the flood event in the river has passed.

The flood hazard for users of the footpath who may be exposed to flood waters is determined from the depth of flooding, velocity of the flood water and the potential for debris within the water. As the relative depth of the flood water is slightly increased between the '*interim design*' and the '*proposed design*' during extreme events, the flood hazard is increased. Details of the management of health and safety for site users is given in Section 5.

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4. Impact of Proposals on Flood Risk

4.1 Footpaths

The impact of the Infrastructure Works on fluvial flood risk was assessed as part of the FRA VNIF-ARP-ZZ-YYY-RP-CD-0002 (Section 5.1 and Appendix A) against the 'consented design'. The principle of riverbank re-profiling along the north bank of the River Irk was included as part of this assessment, and a number of revised bank profiles were fed into the Arup River Irk hydraulic model to determine the impacts on Flood Zone extents and flood levels. Figure 20 and Figure 21 show some of the cross sections which were included in the hydraulic model to represent the proposed bank reprofiling.

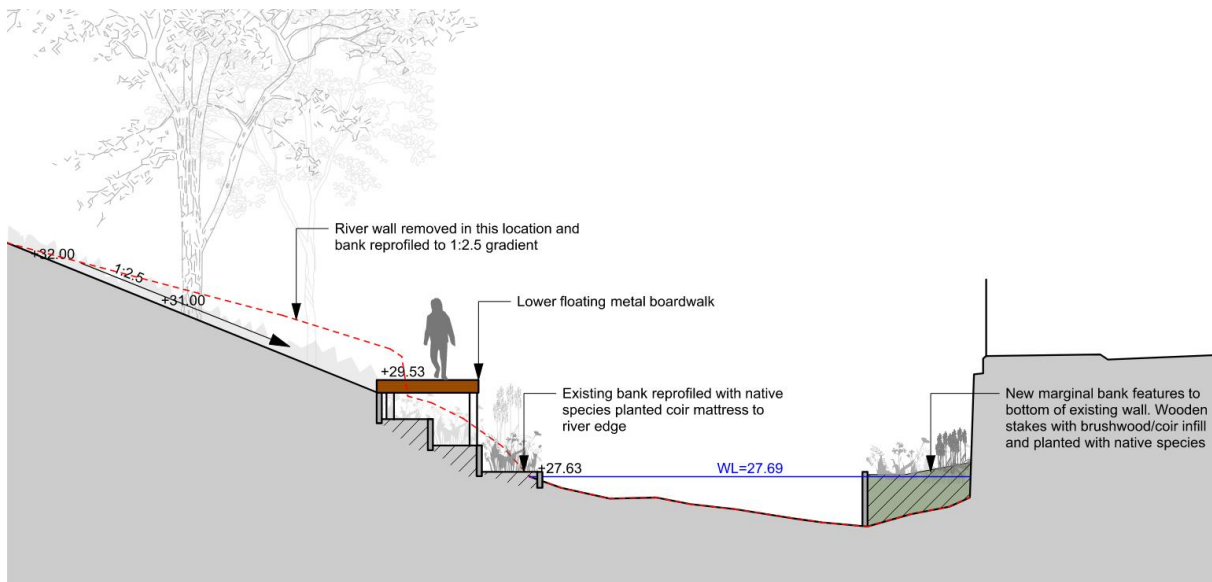


Figure 20 Cross section included in hydraulic model as part of HIF FRA (at St Catherine's Wood, upstream of riverside footpath – cross section view looking upstream)

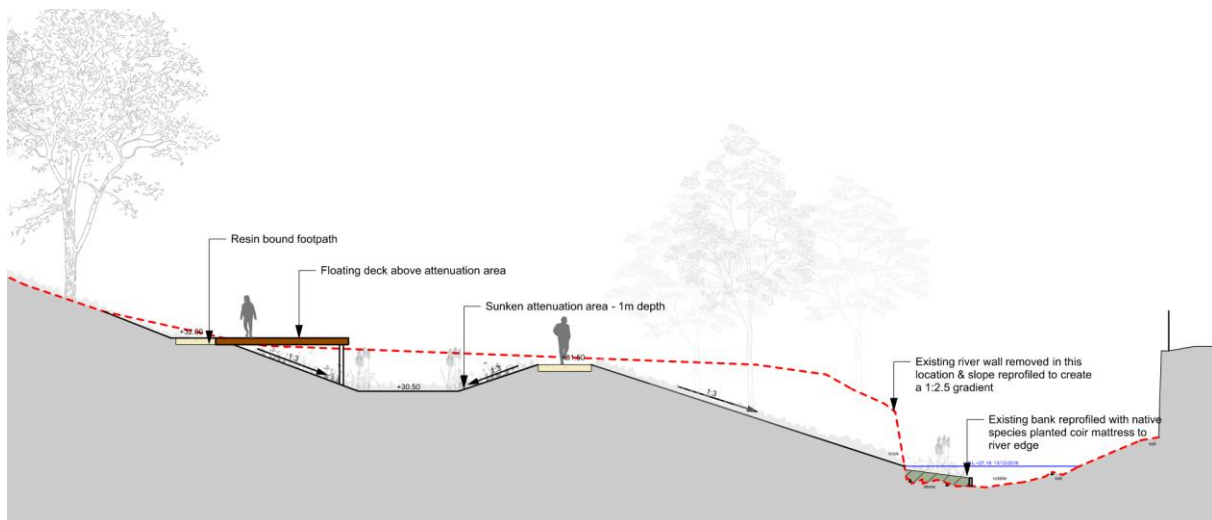


Figure 21 Cross section included in hydraulic model as part of HIF FRA (at location of proposed basin, downstream of riverside footpath – cross section view looking upstream)

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Figure 23 shows a detailed comparison between the '*consented design*' and the '*proposed design*' at 40m intervals along the riverside footpath. These detailed overlays demonstrate that the '*proposed design*' follows the design principles laid out within the '*consented design*', i.e. terracing the riparian corridor to open out the river corridor as compared to the '*original condition*' site levels. The full suite of cross sections which show '*original condition*', '*existing condition*' and '*proposed design*' levels at 5m intervals is provided within Appendix B. Key areas where the design deviates from the levels proposed within the '*consented design*' are at the location of existing UU chambers where cover levels cannot be reduced compared to the '*original condition*', as discussed in Section 2.2.

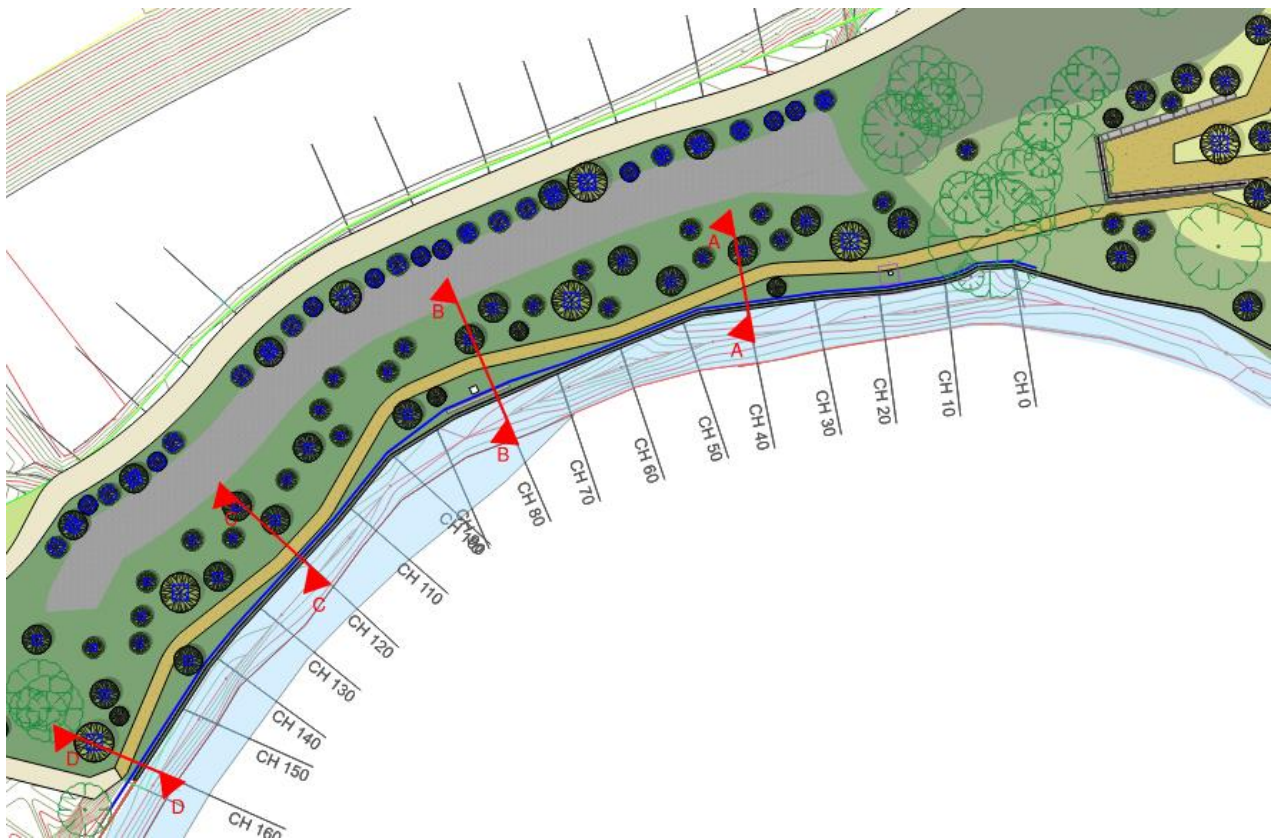


Figure 22 Cross Section Locations Plan

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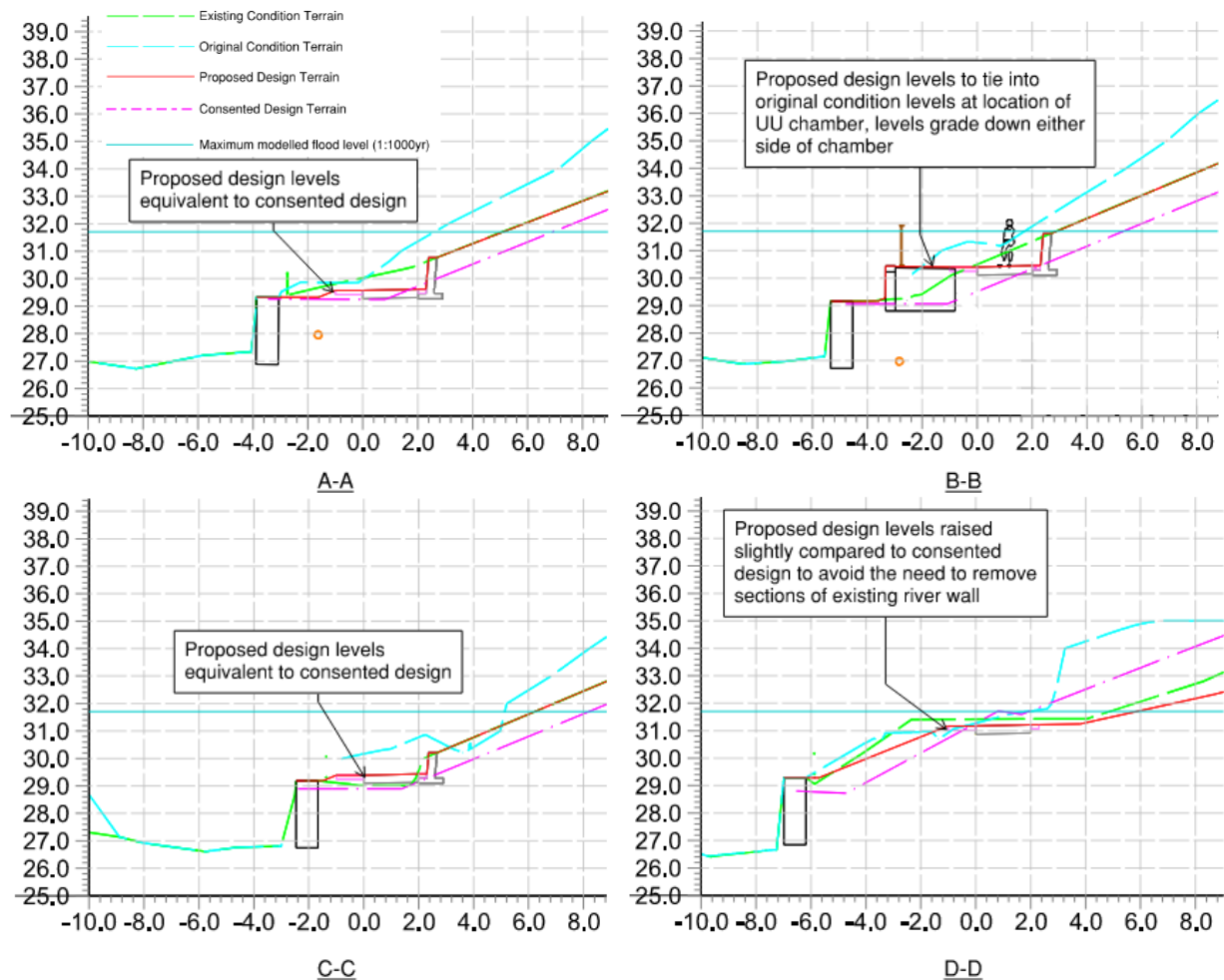


Figure 23 Detailed comparison of 'consented design' vs 'proposed design' at 40m intervals along riverside footpath (travelling North to South from top left to bottom right, see Figure 22 for locations of cross sections)

Hydraulic modelling of the infrastructure works interventions, including bank reprofiling as proposed within the '*consented design*', showed some areas of both increased and decreased extents of Flood Zones 2 and 3. These are shown by the pink (increased extents) and brown (decreased extents) areas in Figure 24 below. The hydraulic modelling exercise concluded that there was a general decrease in flood levels upstream of the HIF works, as more flow is allowed to exit the river channel and fill the floodplain as a result of the bank re-profiling. It also concluded that there were negligible changes to flood levels downstream of the proposed HIF works and no change in levels at the confluence with the Irwell. Small increases in pass forward flow ($0.3\text{m}^3/\text{s}$) were identified through hydraulic modelling in the 1000-year event, however in-channel oscillations and instabilities were noted within the hydraulic model for this event. The '*consented design*' was approved as part of planning application 133143/VO/2022 based on the principles of this flood modelling, including localised changes to Flood Zone extents resulting from the development.

The '*proposed design*' follows the same principles of re-profiling and terracing to the north bank of the river as the '*consented design*', as demonstrated in Figure 23. Whilst there are some minor

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localised areas where the re-profiling in the '*proposed design*' does not lower ground levels as much as the '*consented design*', predominantly around the UU chambers to be retained as per existing, the '*proposed design*' levels are still lower than those in the '*original condition*'. Therefore, the results of the previous hydraulic modelling exercise are considered to adequately demonstrate that the proposed works under Phase 2 of the scheme will not have an adverse impact on flood risk extents.

Through engagement, the EA have requested further clarity regarding flow paths at UU chamber 5501, which is to be maintained at its pre-development level. The pre-development flow within the river channel discussed in Section 3.1.1 are shown to be maintained wholly within channel.

Therefore, as all proposed levels changes are to either maintain or reduce ground levels (compared to the pre-development case), and all levels changes are to the right bank of the river only (wholly within the scheme boundary), it is concluded that any changes to flow routes will be localised and within both the scheme boundary and river channel corridor, and there will be no impacts on flood routes outside of the site under the proposed scheme.

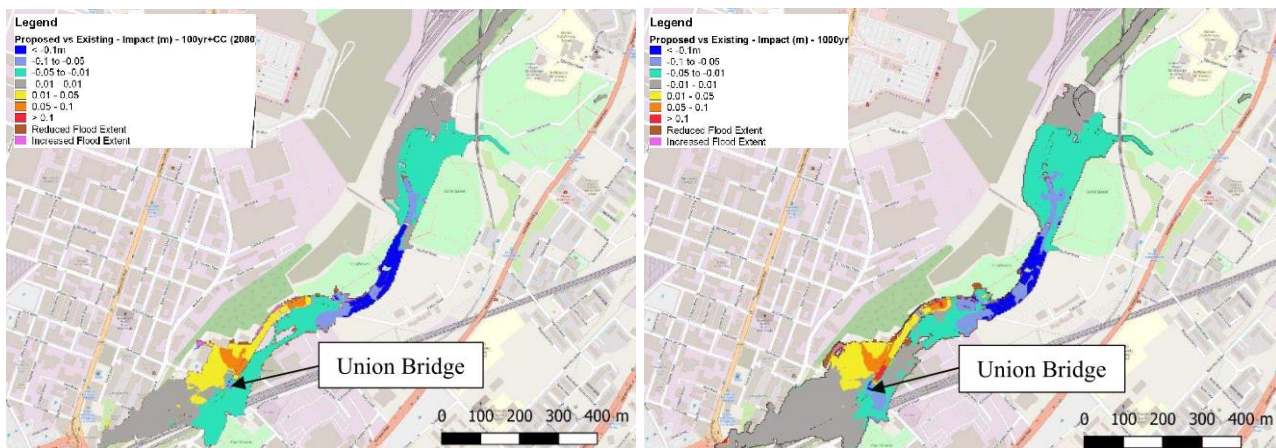


Figure 24 Previous model results showing the impact of the '*consented design*' full HIF works development and bank reprofiling on flood zone extents and flood levels for the River Irk (Flood Zone 3 Left, Flood Zone 2 right). Refer to FRA VNIF-ARP-ZZ-YYY-RP-CD-0002.

As discussed in Section 3.1, a length of the '*proposed design*' footpath sits within Flood Zones 1 and 2, this section is an existing footpath within St Catherine's Wood in the '*original condition*'. The extents of this section are shown in Figure 25 for the '*original condition*'.



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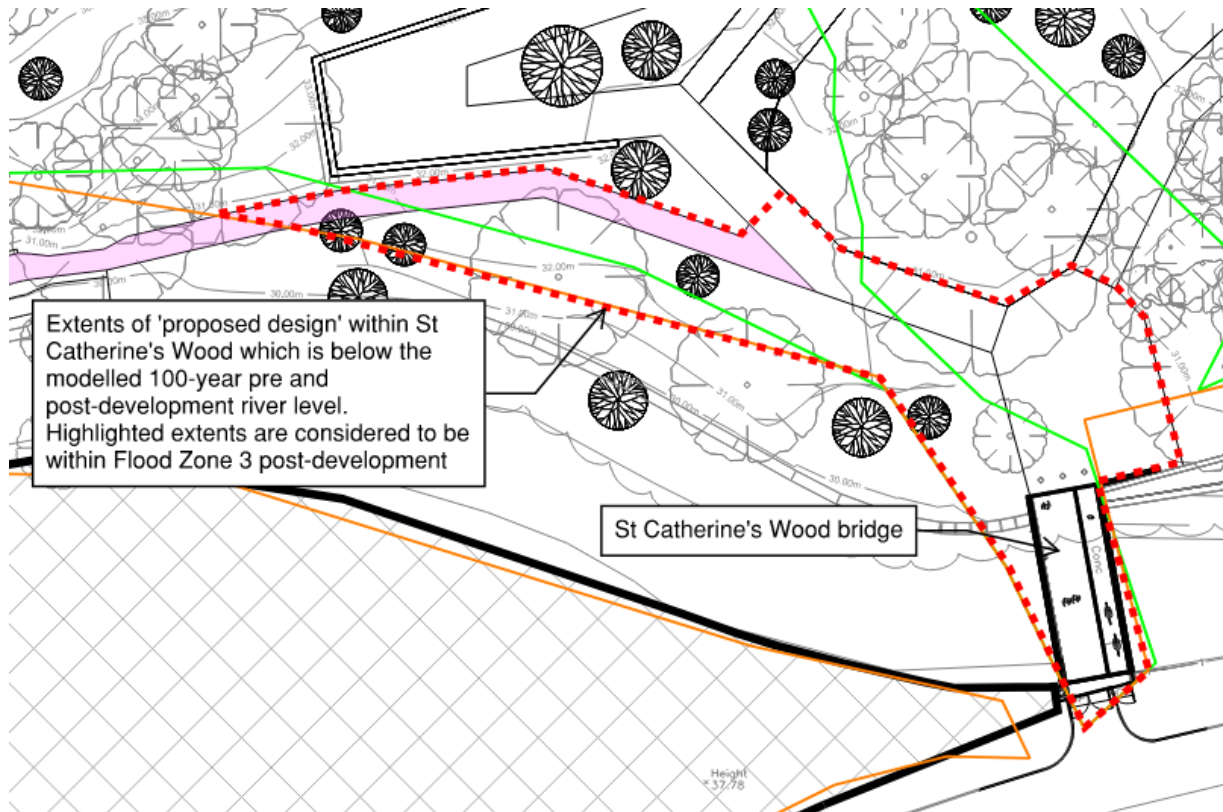


Figure 26 Extents of footpath within increase Flood Zone 3 extent in 'proposed design'

It is worth noting that the previous hydraulic modelling identified an increase in flood extents and levels to the right bank of Union Bridge and continuing south to Roger Street during the 100-year event, this increase resulted from the modelled removal of the existing river wall on the north bank of the river opposite Dantzic Street. In line with the approved HIF Lite proposed works, and the additional works discussed within this note, this wall is not proposed to be removed. Removal of this wall at any future time would trigger the need for a flood mitigation feature, such as the bund presented within the full HIF works FRA, to prevent flood risk from being worsened off-site.

4.2 Bridge and Railings

A balustrade is proposed alongside the riverside footpath to prevent site users from approaching the rivers edge or entering the river channel. The proposed balustrade will run parallel to the river channel and its design includes large apertures and slim crossing bars which provide a minimum equivalent of 90% net clear opening area, the design is intended to prevent the balustrade acting as a barrier to passage of flood waters and reduce the risk of debris collection/blockage. See Figure 27 for a reference image of the proposed railing.

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Figure 27 Example image of proposed estate railing proposed along rivers edge

Drawings showing the existing and proposed condition for St Catherine's Wood Bridge are available in Appendix C. A summary of each feature is provided below.

4.2.1 Structural Repairs

The structural repairs proposed to the bridge consist of localised concrete repairs to the bridge soffit to rectify areas of concrete spalling and exposed rebar. The proposals do not have any impact on the overall soffit level or profile of the bridge against river flows. Refer to Appendix C for proposed bridge repair drawings.

4.2.2 Parapets

The existing bridge parapets are in poor condition, it is therefore proposed that these are replaced with a modern parapet of an equivalent open-bar design, refer to Figure 28.

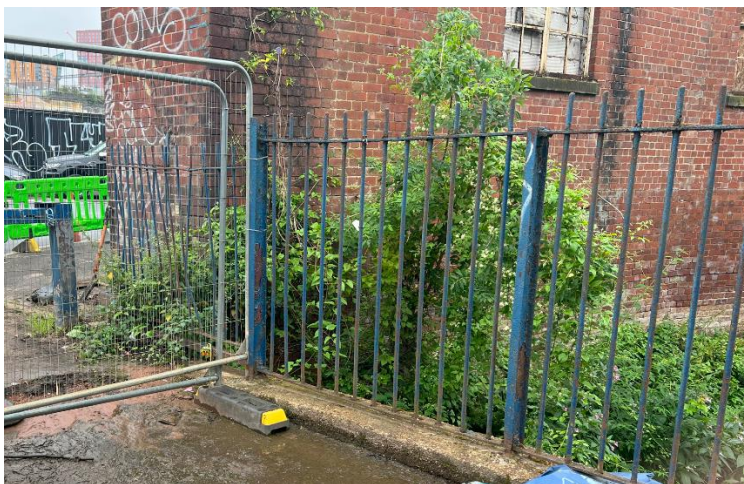
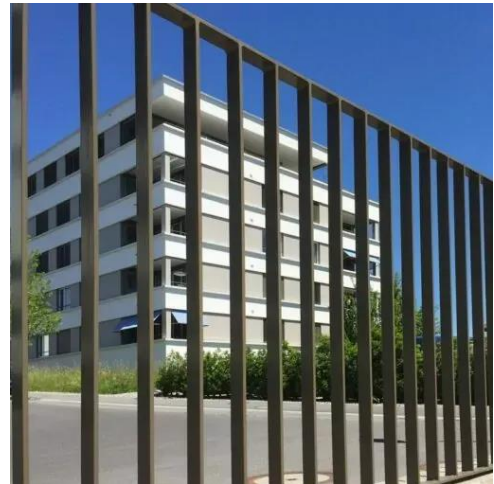


Figure 28 Existing SCW Bridge Parapet (left) and proposed parapet (right) to be Lang and Fulton Rimini railing or similar approved

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4.2.3 HVM Bollards

A sliding bollard system is proposed to the north end of the bridge to provide hostile vehicle mitigation for the park. Bollards are proposed with 1.2m spacing, and therefore they provide a wider clear opening space than the existing bridge parapets. It is therefore concluded that the bollards will not pose as a barrier to flood flows and will not trap large debris (tree branches etc) any more than the existing parapet railing.



Figure 29 Reference image of bollards proposed to north of bridge

4.2.4 Surfacing

The proposed surfacing intent for the bridge is to replace the existing asphalt surfacing with stone paving setts. The proposed finished level of the paving is level with or lower than the edge beams of the bridge across the full width, so there will be no impact on the overall profile of the bridge deck with respect to river flows. Refer to Appendix C for details of proposed surfacing.

4.2.5 Gate

The proposed gate sits within the 26m section of the left bank of the river which was identified to be a location where flow exchange occurs between in-channel and out-of-bank on Collyhurst Road (see Section 3.1.1), in the pre-development situation.

As a result, and following engagement with the EA, the design for the gate has aimed to achieve the highest clear opening area while still meeting security and aesthetic requirements, in order to avoid altering this flow regime. The proposed design for the gate is shown in Figure 30 and Appendix C.

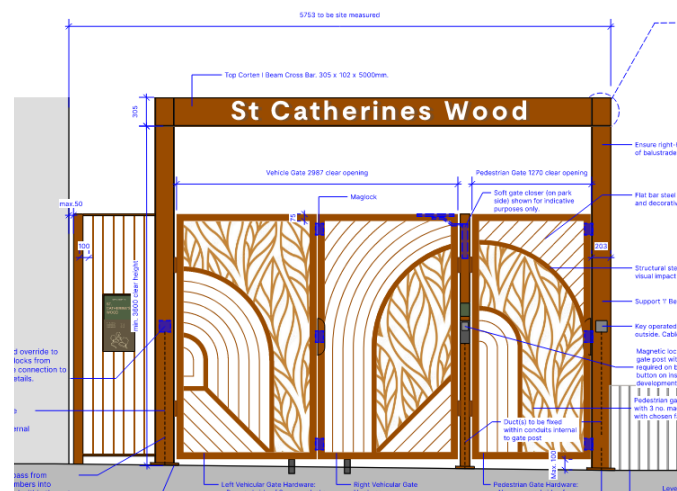


Figure 30 Proposed design for St Catherine's Wood gate

A review of the clear opening/void area above ambient ground level, between the existing and proposed condition cases over the 26m length of river bank has been undertaken. Table 2

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demonstrates that the change in void area over this length between the existing and proposed gate design is between 2.8% and 7.2%, depending on the depth of flow considered.

The void area has been calculated at depths of 100mm (the underside of the proposed gate to account for the new posts), 480mm (the maximum 20-year flood depth based on the 2022 baseline model) and 1380mm (the maximum 100-year + CC flood depth based on the 2022 baseline model). These levels have been chosen as sample heights to demonstrate the impacts at key flood depths, however the conclusion that the relative change between existing and proposed is negligible could have been calculated for a different range of flood depths against the gate. Full calculations can be found in Appendix C.

Table 2 Void area comparison between existing and proposed condition along 26m re-entry length of flows into the river channel

Flood Depth	Void Area over 26m re-entry length (m ²)				Commentary
	Existing	Proposed	Absolute change	% Change	
100mm	2.22	2.15	-0.06	2.8%	Change is due to presence of the new gate posts only
480mm (20yr)	10.56	9.81	-0.76	7.2%	Change is due to presence of the new gate posts and leaf pattern of the gate
1380mm (100yr + CC)	30.22	28.49	-1.72	5.7%	Change is due to presence of the new gate posts and a less dense leaf pattern at this height

Based on this review, the change in void ratio resulting from the proposed gate is not considered to act as a barrier to flows re-entering the river channel. During the EA engagement session on 17/09/2025, the principle of the gate design was agreed based on the analysis presented in Table 2.

5. Rate of Rise of Flood Water and Health and Safety Management

To enable the management company for the park (Found) to develop a flood management strategy, the rate of rise of the River Irk has been determined based on the previous Arup hydraulic modelling at nodes adjacent to the riverside footpath. Both the 'baseline' and '*consented design*' models were reviewed to determine the most critical case for rate of rise adjacent to the riverside footpath. The following have been determined:

- The time delay between the river beginning to rise from the onset of a storm and the **footpath first overtopping** is between **4.5 and 6.25 hours** depending on the return period and location along the river edge that is considered.

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- The time delay between the river beginning to rise from the onset of a storm and reaching its **maximum modelled level** (up to the 100yr + Climate Change event) is between **8.5 and 9.3 hours** depending on the return period and location along the river edge that is considered.

Figure 31 shows stage hydrographs at two nodes at the downstream side of the riverside footpath as modelled for the baseline and '*consented design*' scenarios, the level at which the footpath is first overtopped at each node is also shown. These have informed the Found flood management strategy for the park during a flood event, refer to Appendix A for details of this strategy.

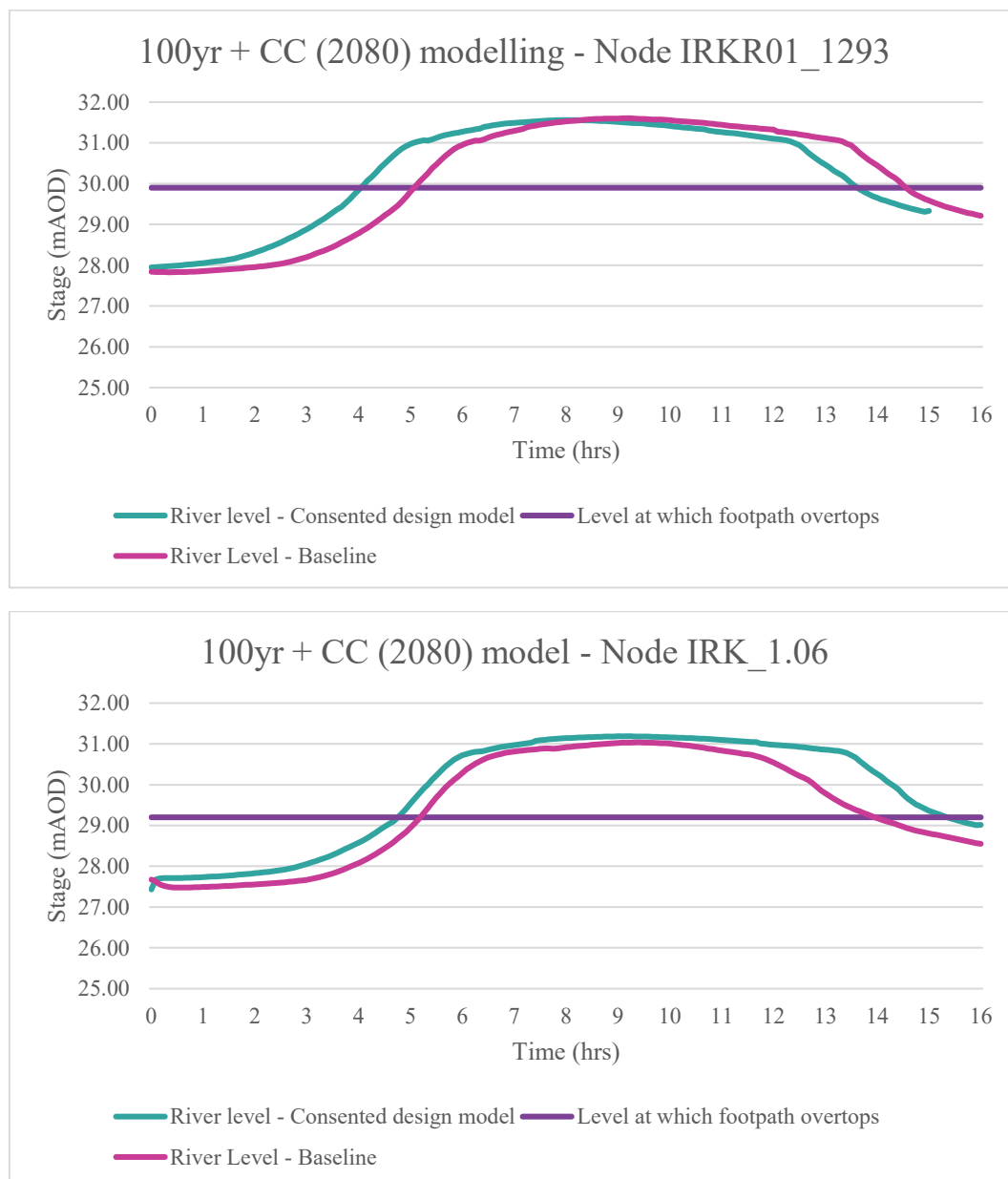


Figure 31 Stage hydrographs at 2 nodes adjacent to the riverside footpath for the 100yr + CC (2080) event baseline and 'consented design' models

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6. Other Considerations

The EA raised additional requests related to lighting and planting adjacent to the river within the consultation letter *ENVPAC.1.GMC.00580 - VN HIF 24-25 - EA Preliminary Review - Riverside Walkway & Embankment Technical Note - Issued 11.07.2024*.

Lighting: The EA's request for lighting adjacent to the river to include directional cowling is reflective of the principles set out within the current lighting design for the scheme. Details of the lighting design will be shared as part of the Phase 2 planning submission.

Planting: All proposed planting within Flood Zones 2 and 3 has been selected to be resilient to periodic inundation by flood water as requested by the EA. Details of the proposed planting mix will be shared as part of the Phase 2 planning submission.

7. Flood Risk Conclusions

Both the approved '*consented design*' and the '*proposed design*' for the riverside footpath and EA footpath, as well as the proposed design for St Catherine's Wood Bridge, include a significant portion of the works to be constructed within Flood Zone 3.

Under the National Planning Policy Framework, the proposed footpaths and bridge amendments can be considered as 'amenity open space' which is classified as water-compatible development and is allowable within Flood Zone 3. Previous hydraulic modelling undertaken by both Arup and WSP shows that a proportion of the footpath sits beneath the 1% AEP flood level in both the existing and post-development scenario, the proposed features have therefore been designed to withstand hydraulic loading during flood events within the river. The risk to users of the footpath will be mitigated by the management company of the park, and the design of the park will allow for access to be restricted during a flood event. It is therefore concluded that **the proposed design, including proposed footpaths, bridge works and overall re-profiling strategy of the river embankment is suitable in relation to the pre and post-development flood levels within the river, and is in line with the approved principles within the HIF FRA.**

The impacts on flood risk of the '*proposed design*' footpaths and embankment have been considered within this assessment. The proposed footpath levels are to be reduced compared to the '*original condition*', which would provide additional flood storage volume during a flood event.

The principle of bank re-profiling was hydraulically modelled as part of the HIF FRA and the comparison between the modelled levels and current proposed levels made within this note have shown that the designed levels are very close in nature to those previously modelled. This assessment found that there were some localised areas of increased Flood Zone extents as a result of the re-profiling, but that the impact on downstream flood levels and pass forward flows was negligible. There will be localised increased extents of Flood Zone 3 within the Phase 2 area as a result of the design, which was also the case under the approved '*consented design*'. No new flood mechanisms are created as a result of the proposals, and additional flood storage is provided through the re-profiling of the embankment when comparing the '*proposed design*' to the '*original condition*'.

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The relative change in void area between the existing and proposed case for the St Catherine's Wood gate is compared within this note to demonstrate that the relative change is negligible in terms of it's potential to impact on flood risk.

Therefore, it is concluded that **the '*proposed design*' including proposed footpaths, bridge works and overall re-profiling strategy of the river embankment (as summarised in Section 2.2) has no adverse impact on flood risk elsewhere and is in line with the approved principles within the HIF FRA.**

Based on the above, it is concluded that **the proposed design, including footpaths, bridge, gate and overall re-profiling strategy of the river embankment is suitable for construction within Flood Zone 3.**

	Prepared by	Checked by	Approved by
Name	Emily Stoddart	Emma Cecil	Tom Saville
Signature			

Appendix A Found Flood Management Strategy

St Catherines Wood: Flood Management Strategy

The below is an evolving strategy detailing Found's approach to management of St Catehrines Wood during a flood event.

There are limitations in the development of our approach which we anticipate will be addressed by the development and sharing of Flood Risk Assessments and Management Plans for future phases of the development. We will work with the Environmental Agency and other partners and stakeholders to ensure that we are unified in the agree approach.

Flood Monitoring & Alerts

- **Flood Warning Service:** We intend to register for the Environment Agency's Flood Warning Service to receive timely alerts about potential flood events. The following Managers will be signed up to ensure continuity during absences:
 - Facilities Manager - Estates & Neighbourhoods Manager
 - Head of Customer Experience

This will ensure the management team are informed at the earliest opportunity when flood risk is rising. Alerts from the EA will trigger our internal flood procedure.

Advance Warning to the Public

- **On-site Signage:** Permanent signage will be placed at key park entrances and along the riverside footpath, informing users that the path lies within a flood zone, that river levels can rise rapidly, and that it may become impassable without warning.
- **Incident Signage:** When flood alerts are received, temporary warning signage will be deployed at all entrance points to advise users of rising risk and possible closure.
- **Digital Communication:** Messaging will be supported via digital channels (portal, website, social media pages).

Closure and Evacuation Procedures

- **Park Closure:** Once a flood alert is received and rising water levels are forecast, our approach will depend on the time the notification is received.
 - Prior to park opening: all gates will remain closed. Signage will be erected explaining the reason for the closure and providing contact details for further information.

- After park opening (but prior to flooding): all gates will be closed and manned. Where still safe to do so, staff will perform a sweep of the park and escort members of the public to safety.
- After park opening (where conditions are no longer safe: We will ensure that all gates are secure, and will alert the emergency services to support with evacuation.
- **Evacuation Support:** Public will be directed to higher ground and away from low-lying areas. Initially this will be towards existing exit points in SCW Phase 1, with further northern escape routes to become available in future phases once the hoarding line is removed. During construction, we anticipate that the hoarding line on the plateau would serve as a muster point outside the flood zone, until public could be led through the site gate and down the access road to safety.
- **Emergency Services/EA Access:** The route outlined above will also serve as an access point for the EA and emergency services. Site will be manned 24/7 and this can be used to facilitate access to emergency services.
-
- **Access Control:** Re-entry to the park will be prevented for the duration of the flood event and until safety has been confirmed via post-event inspections.

Emergency Response Procedures

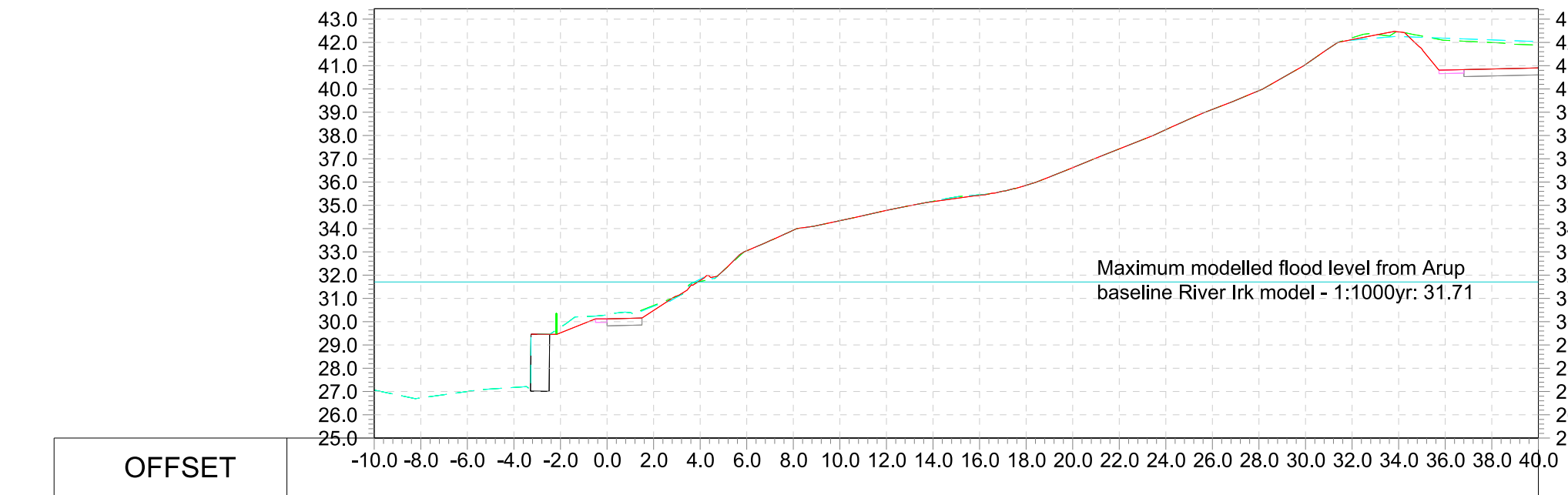
- **Stranded Individuals:** If a park user becomes stranded or enters floodwater and contacts Found, we will contact emergency services and, where trained and safe to do so, guiding individuals to safety.
- **Emergency Contacts:** On-site team members will be briefed on the location of flood-prone zones, emergency access points, and will hold a directory of emergency contacts including the EA incident hotline and local emergency responders.
- **Incident Reporting:** All flood-related incidents will be recorded and reviewed to inform future improvements to procedures and communications.

Post-Flood Inspection and Reopening

- Once the flood event has passed and river levels have receded, we will carry out a site inspection to assess any residual hazards, damage or debris, before reopening affected areas of the park to the public.

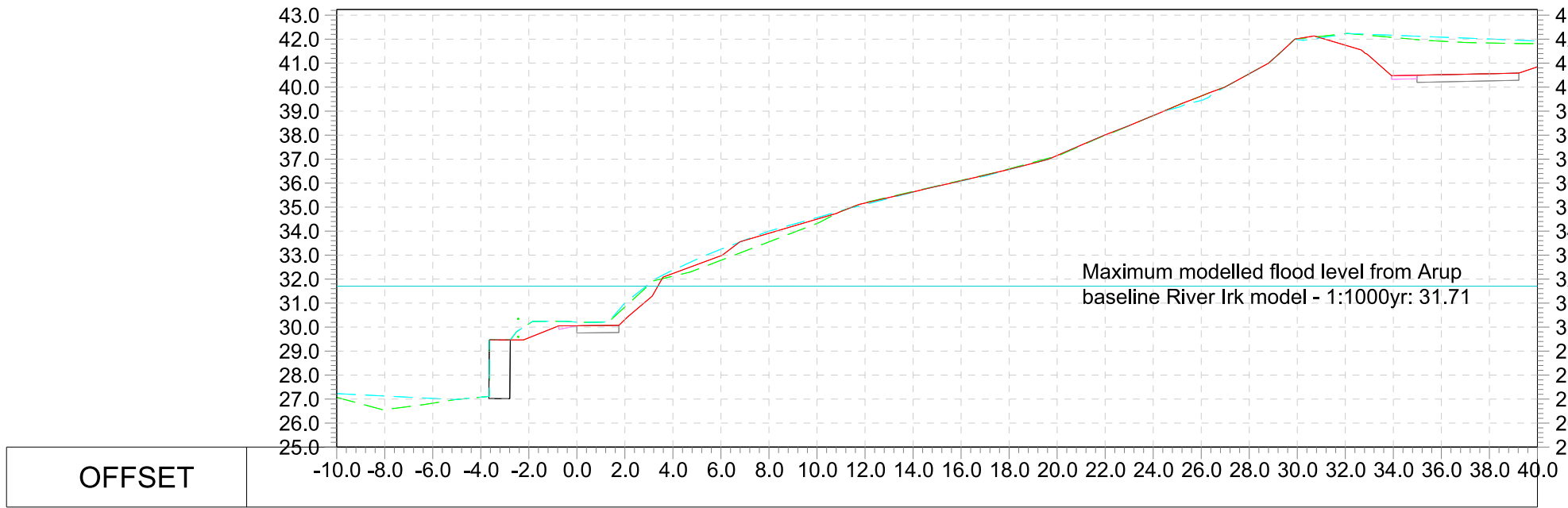
This plan will be periodically reviewed with the board of the Neighbourhood Management Company and refined in collaboration with the Environment Agency and wider stakeholders as operational experience develops, and as access routes evolve through later phases of development.

Appendix B Riverside Footpath Drawings and Cross Sections



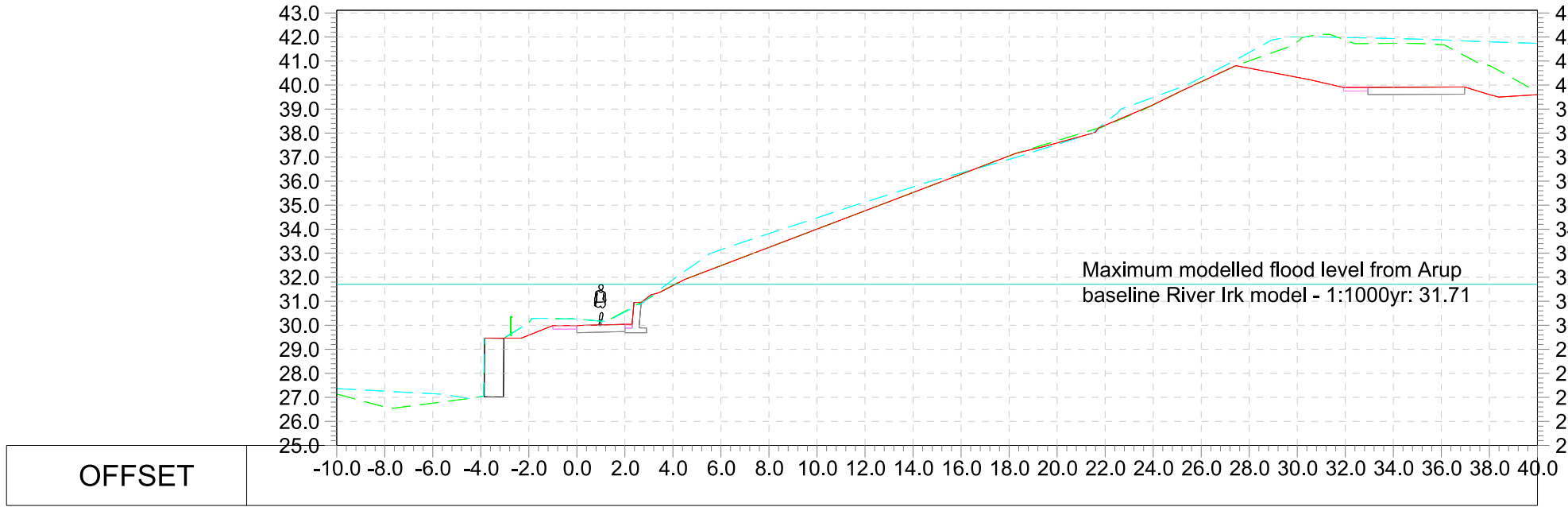
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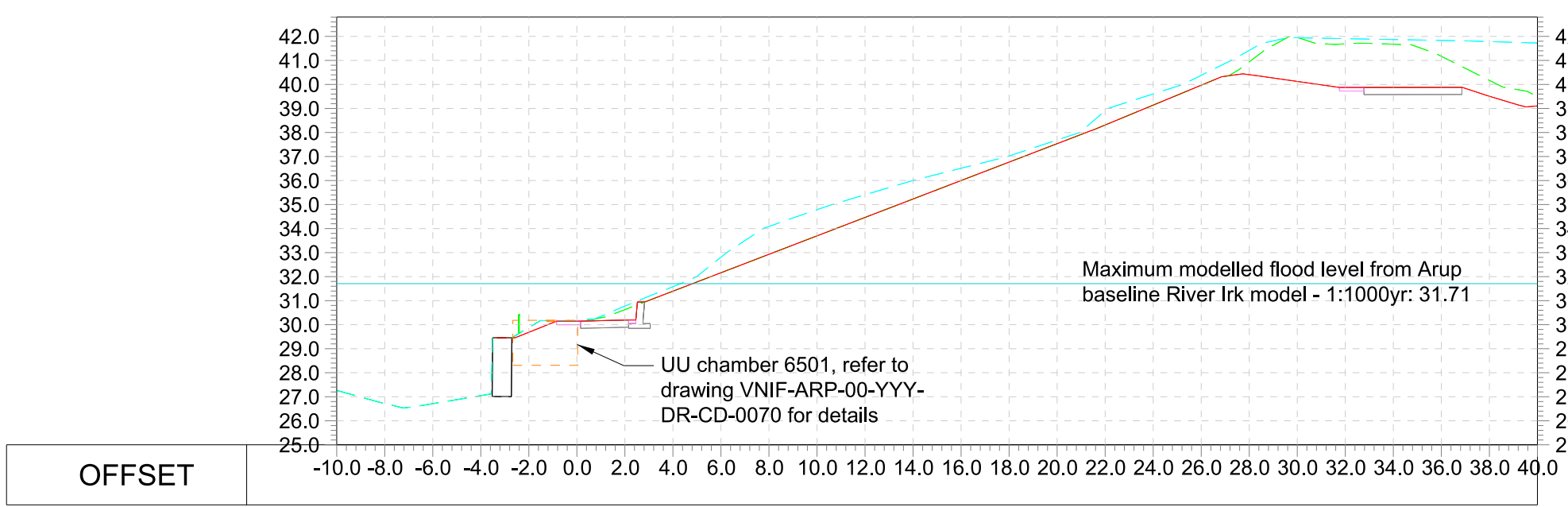
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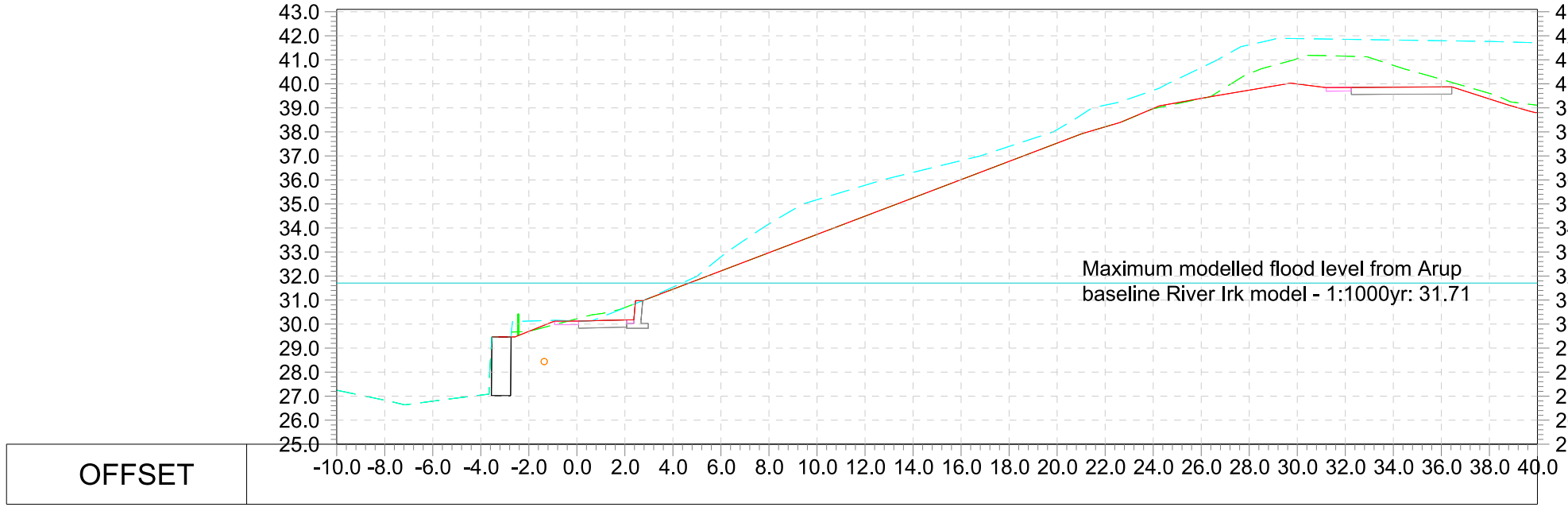
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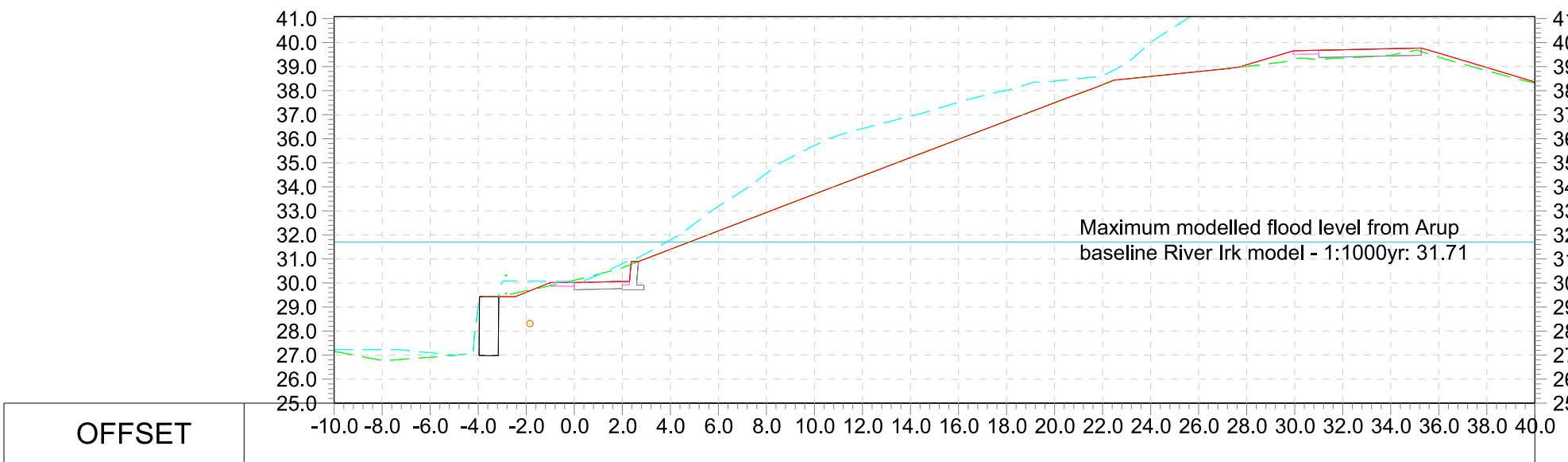
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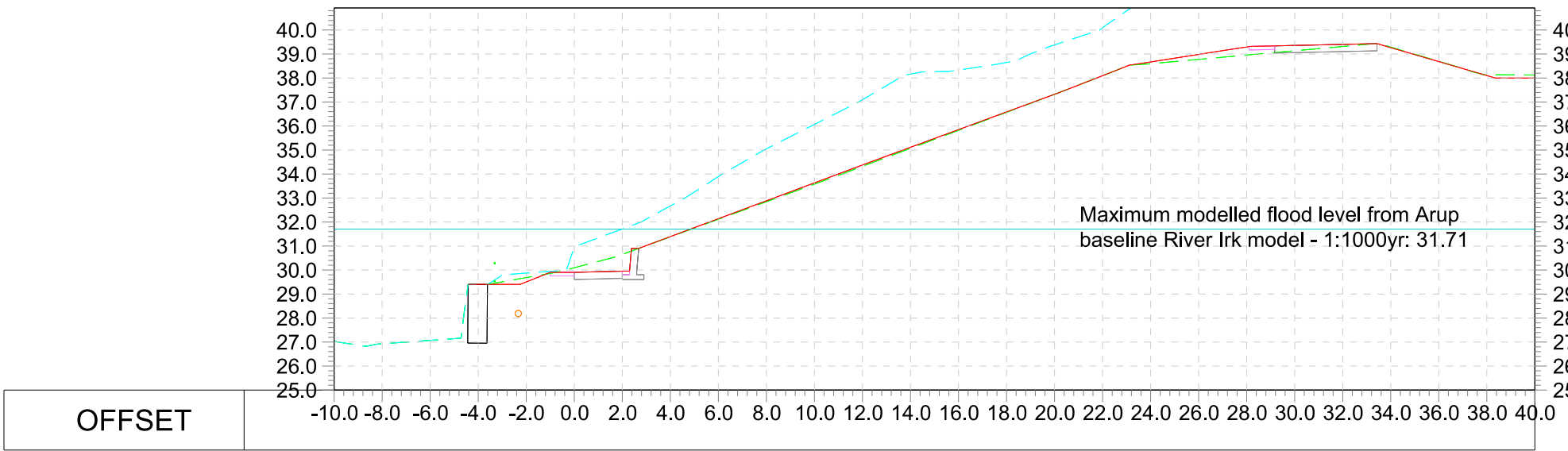
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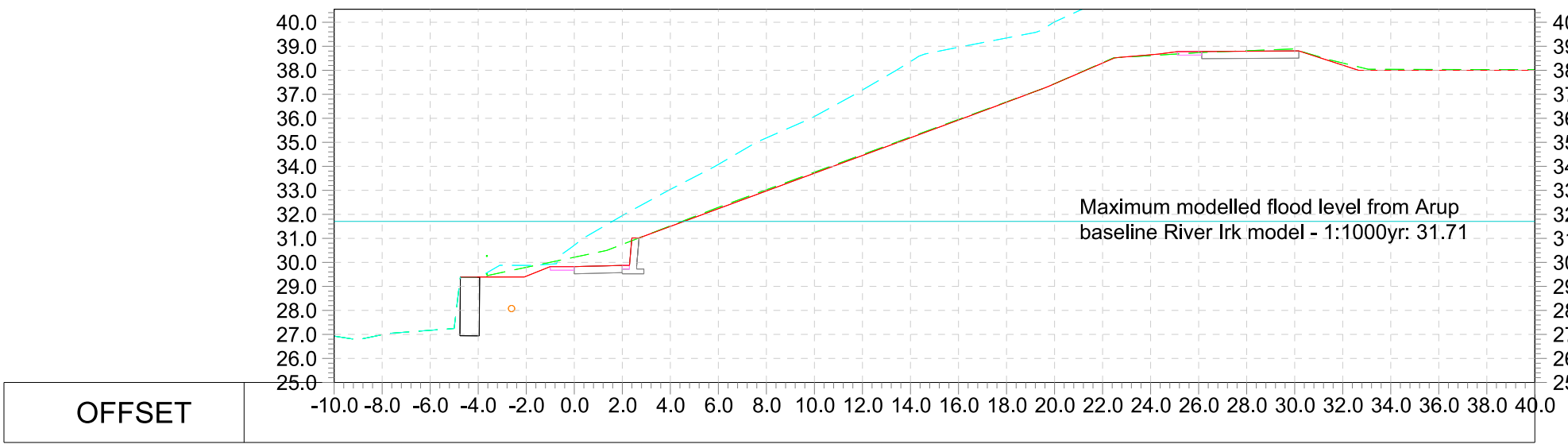
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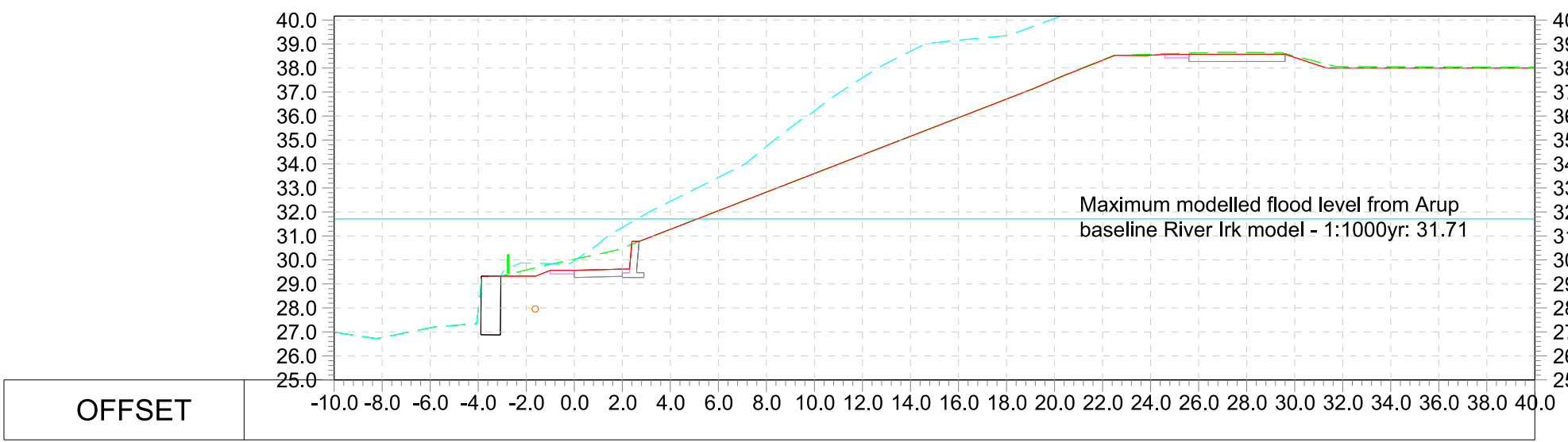
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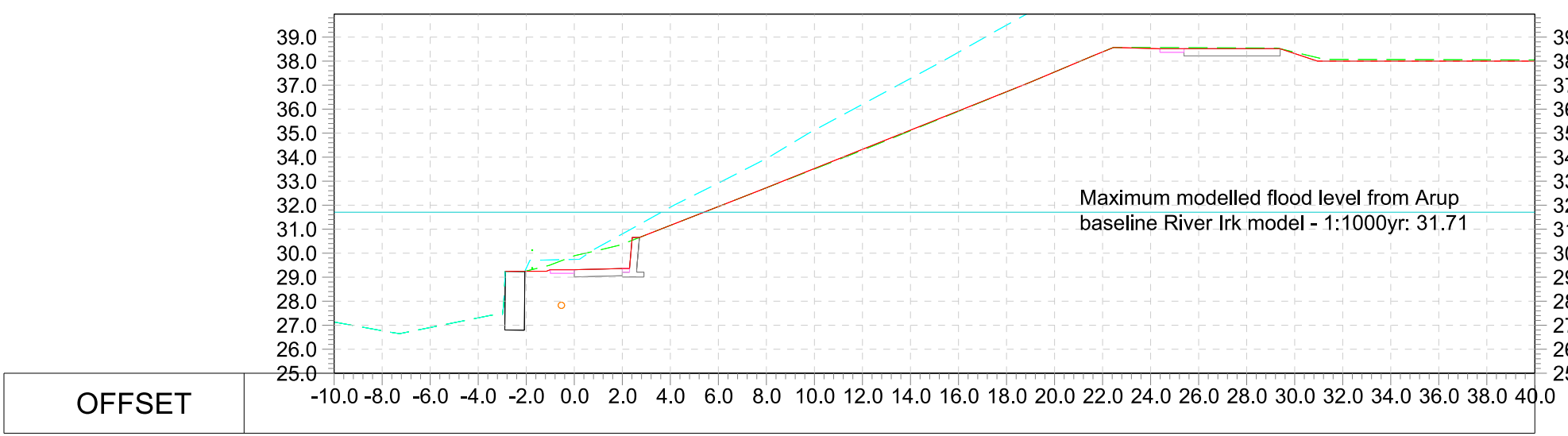
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Cross Section CH45.000

Horizontal Scale 1:250
Vertical Scale 1:250

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- Refer to drawing VNIF-ARP-ZZ-YYY-DR-CE-0020 for cross section locations.
- This drawing is for coordination, it is not an installation drawing.
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- For SHE box hazards and risks see general arrangement drawing VNIF-ARP-ZZ-YYY-DR-CE-0020.
- Retaining wall sections are shown indicatively on this drawing. Refer to Drawing CS-0024 for detailed wall sections.

Key

- Proposed riverside footpath with verge and indicative retaining wall. Retaining wall is to be Redi-Rock blocks, or similar approved, as agreed in principle with the EA
- Existing Terrain
- Pre-development Terrain
- Proposed Terrain
- Proposed Railing
- Existing River Wall
- Existing UU Sewer

P01	20/06/25	First Issue	AS	ES	GL	—
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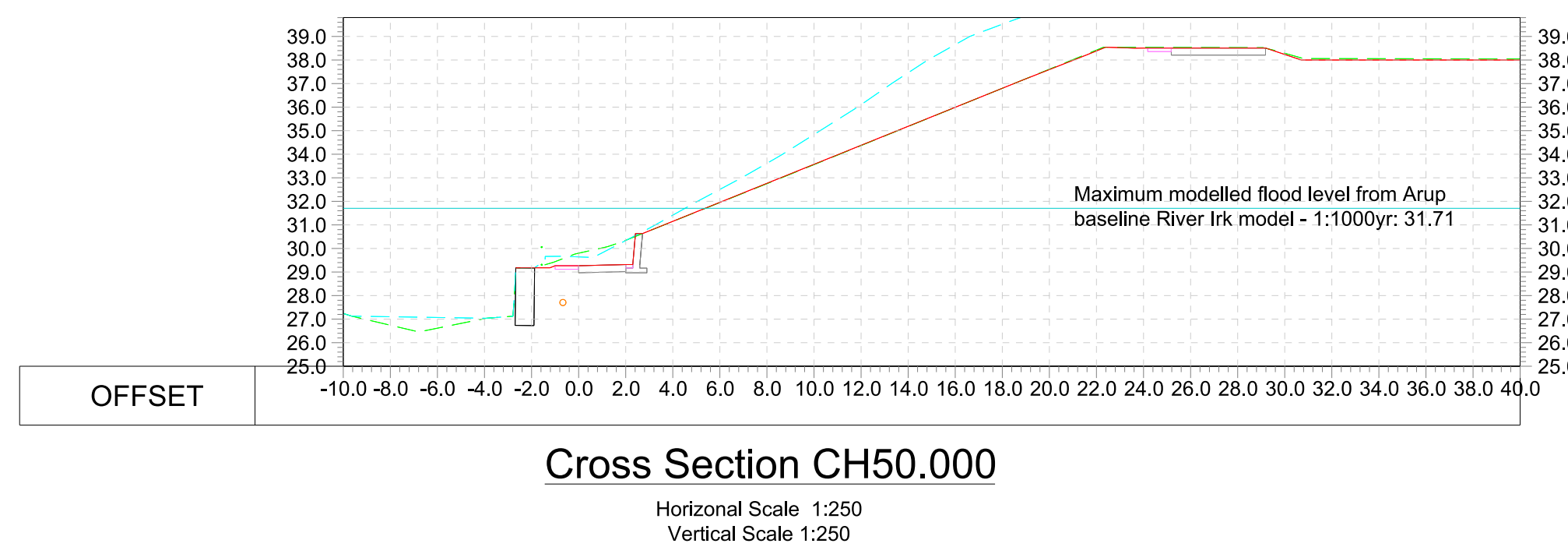
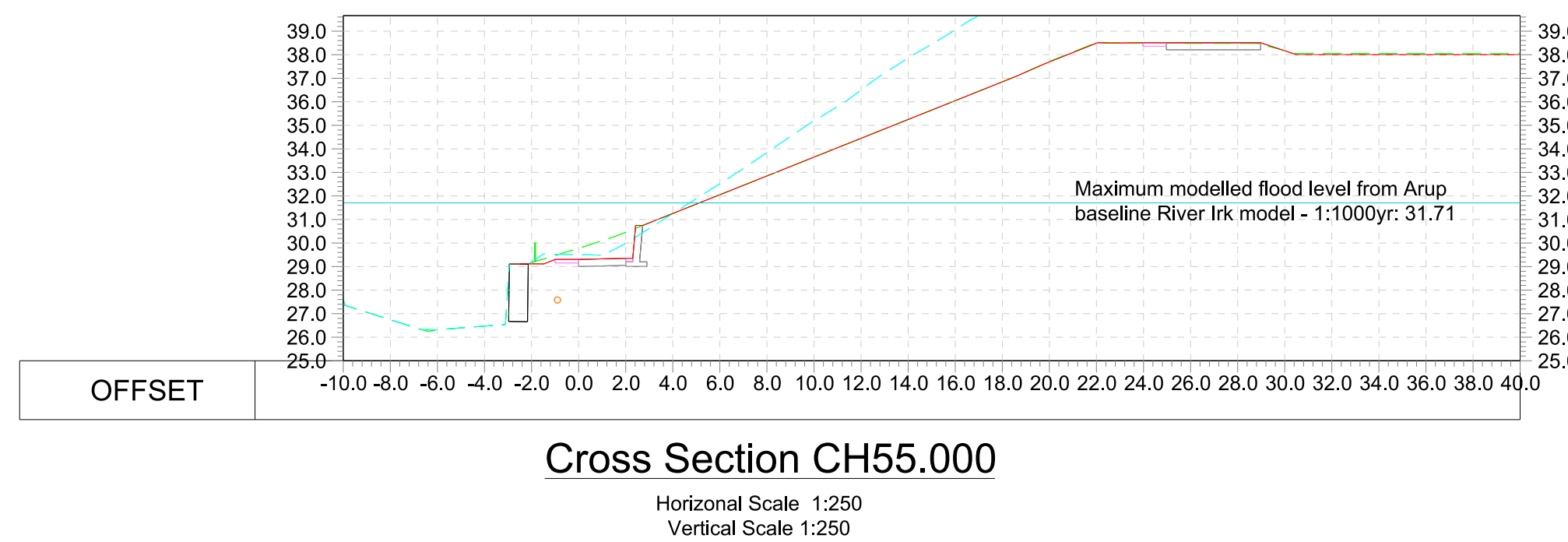
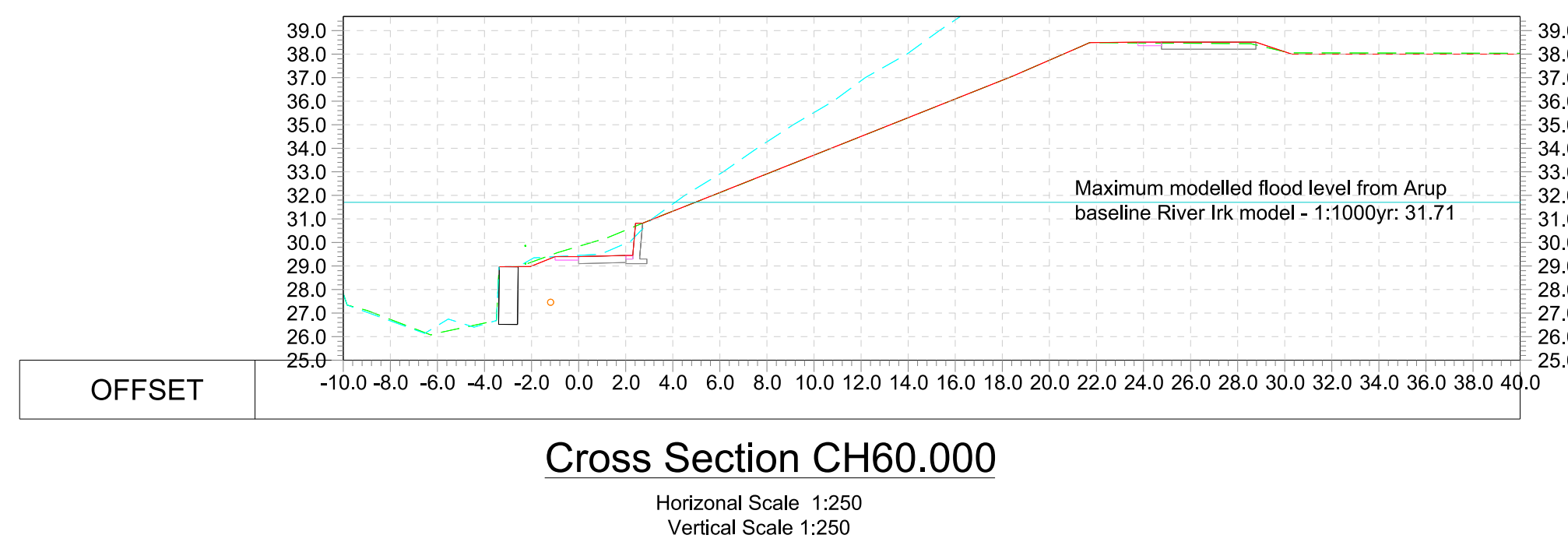
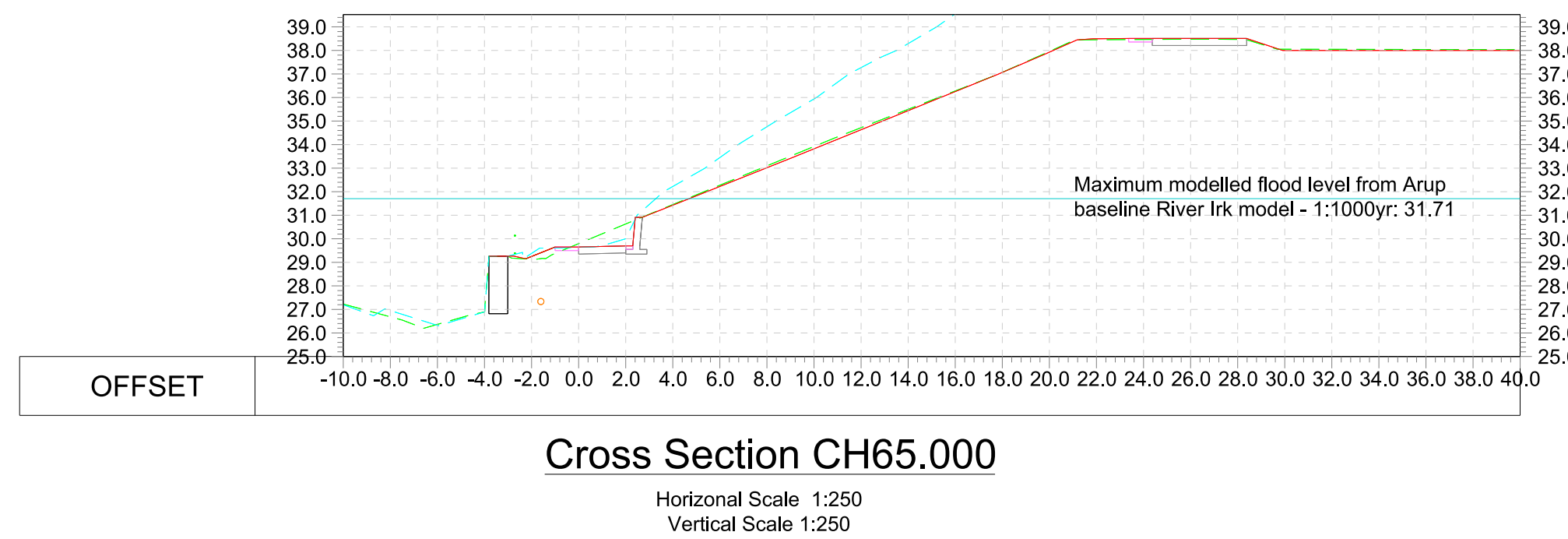
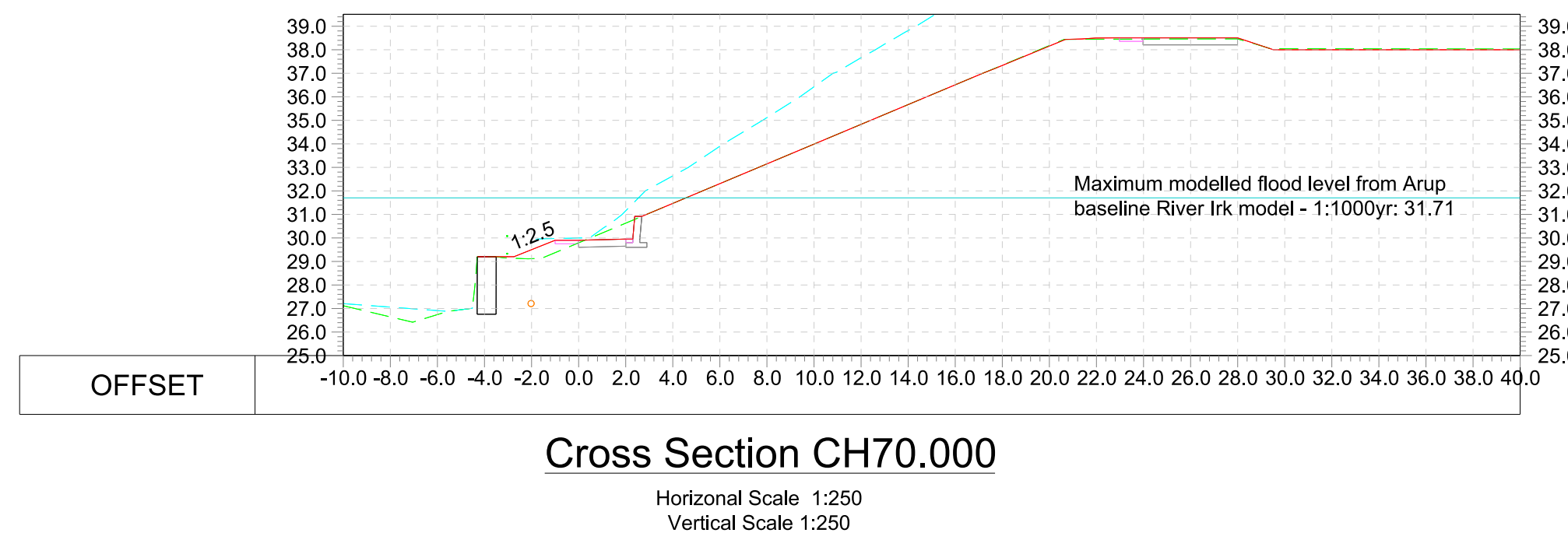
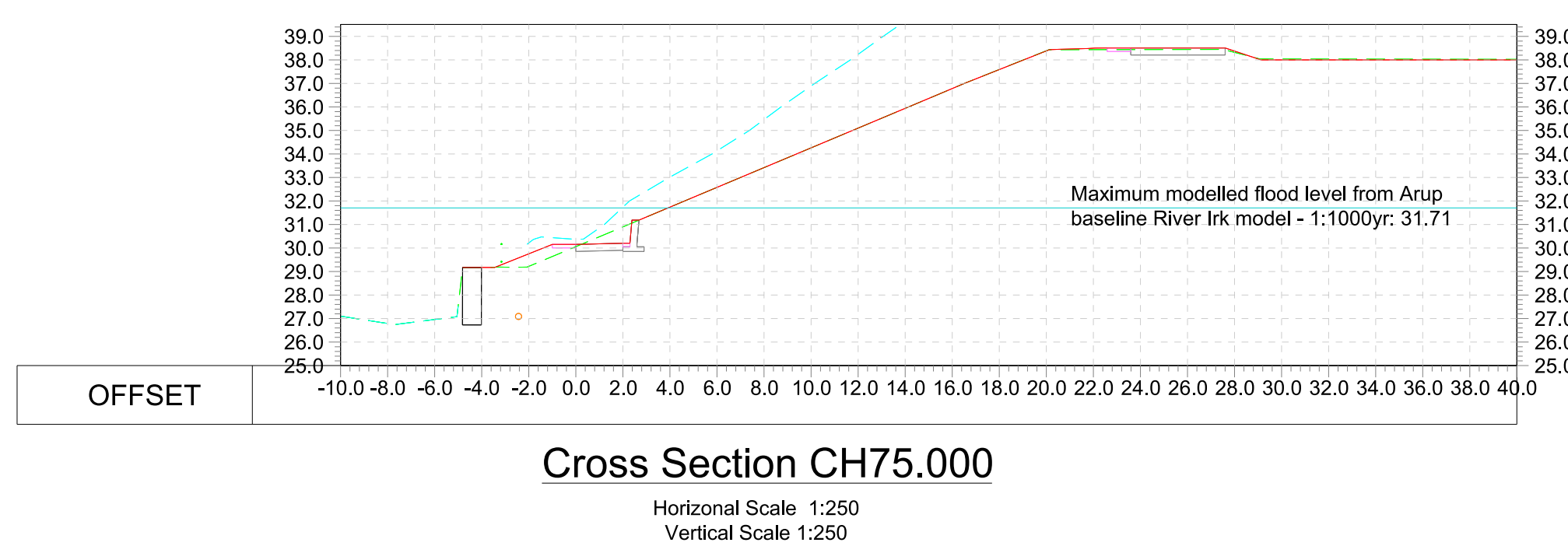
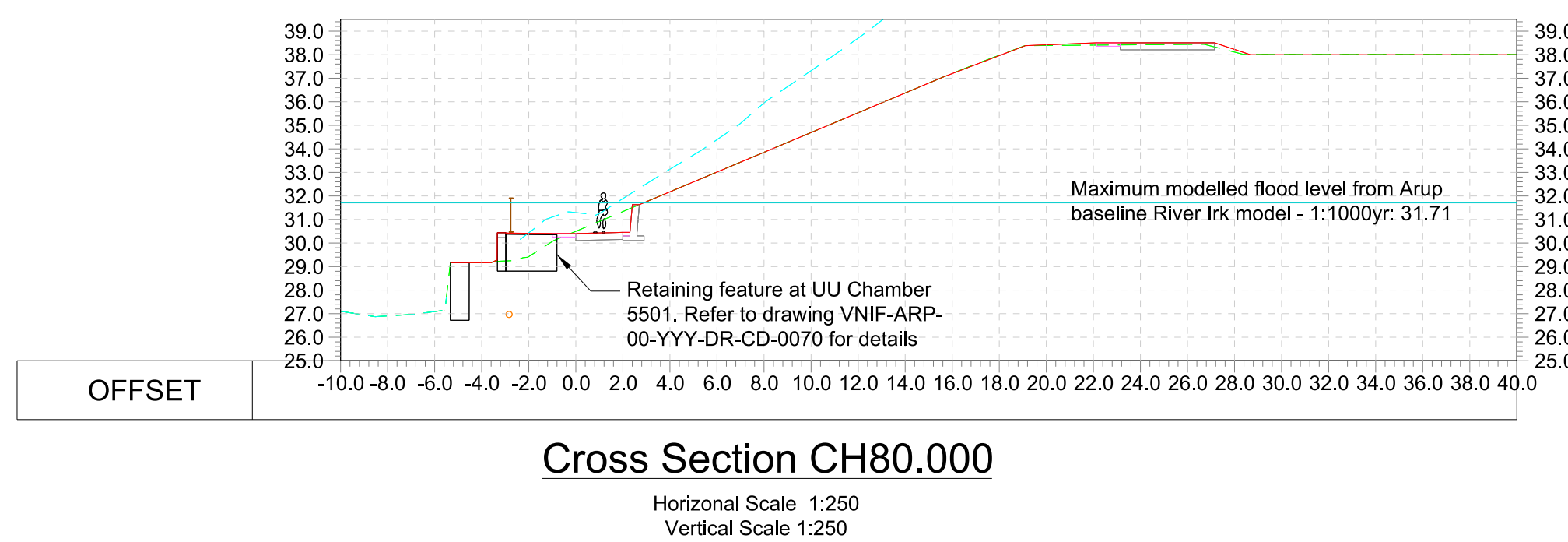
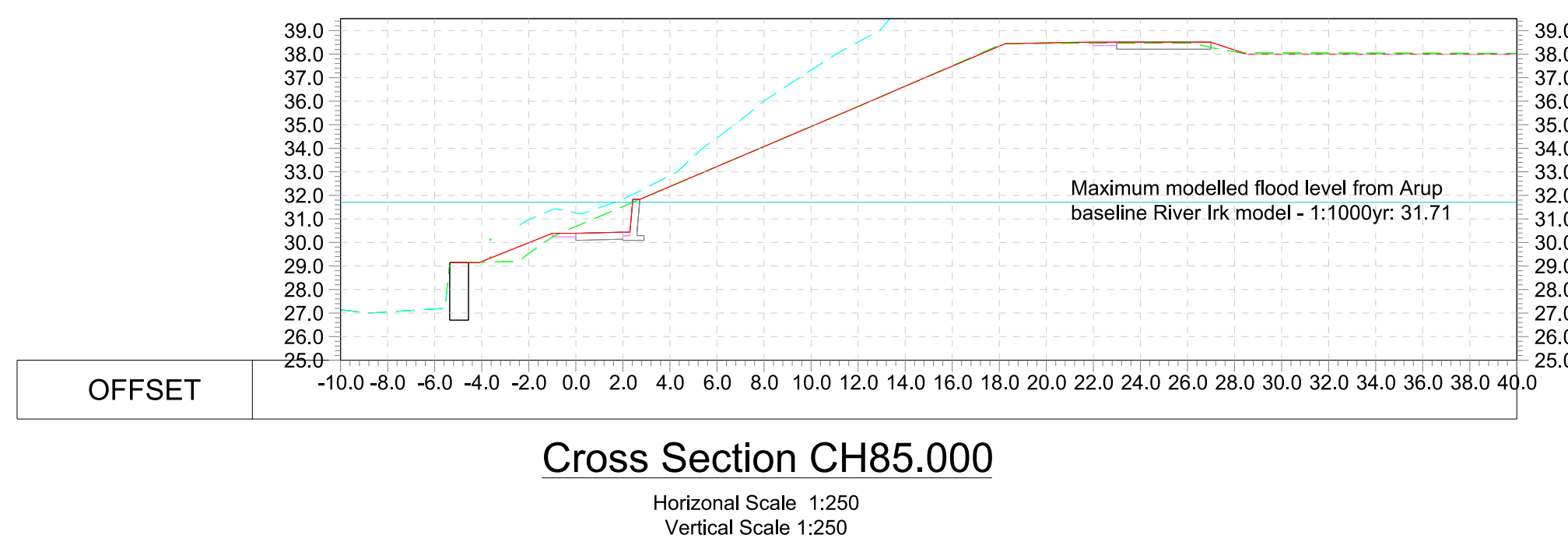
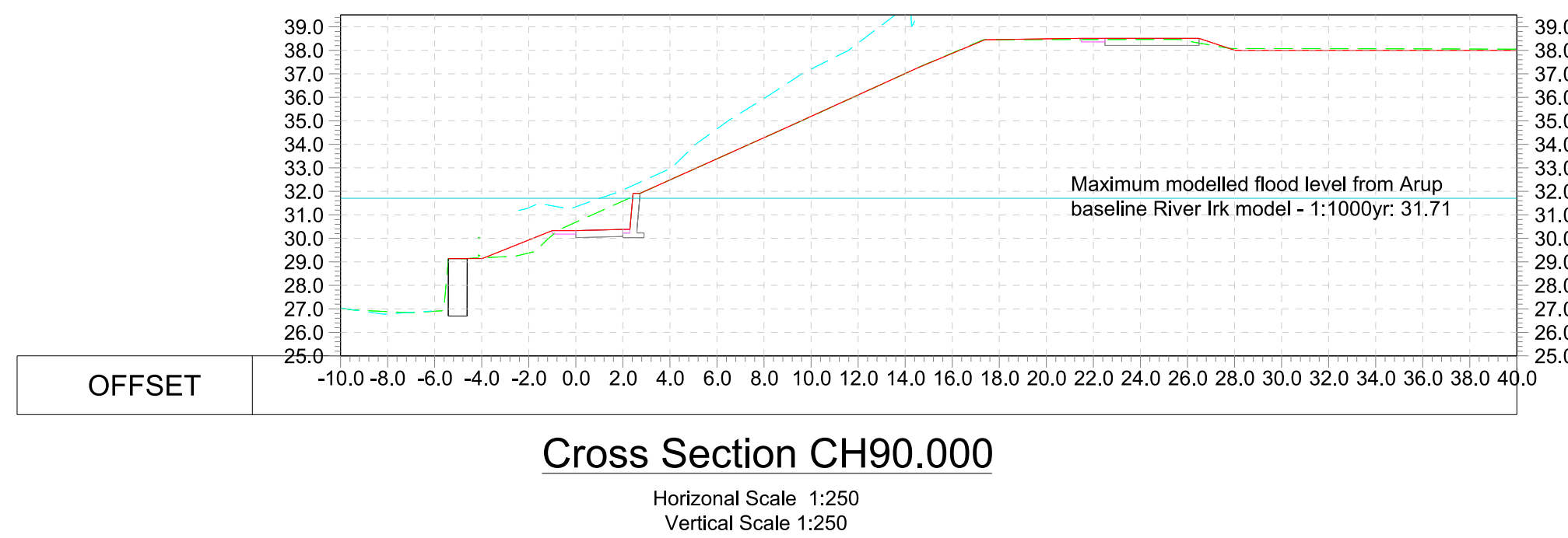
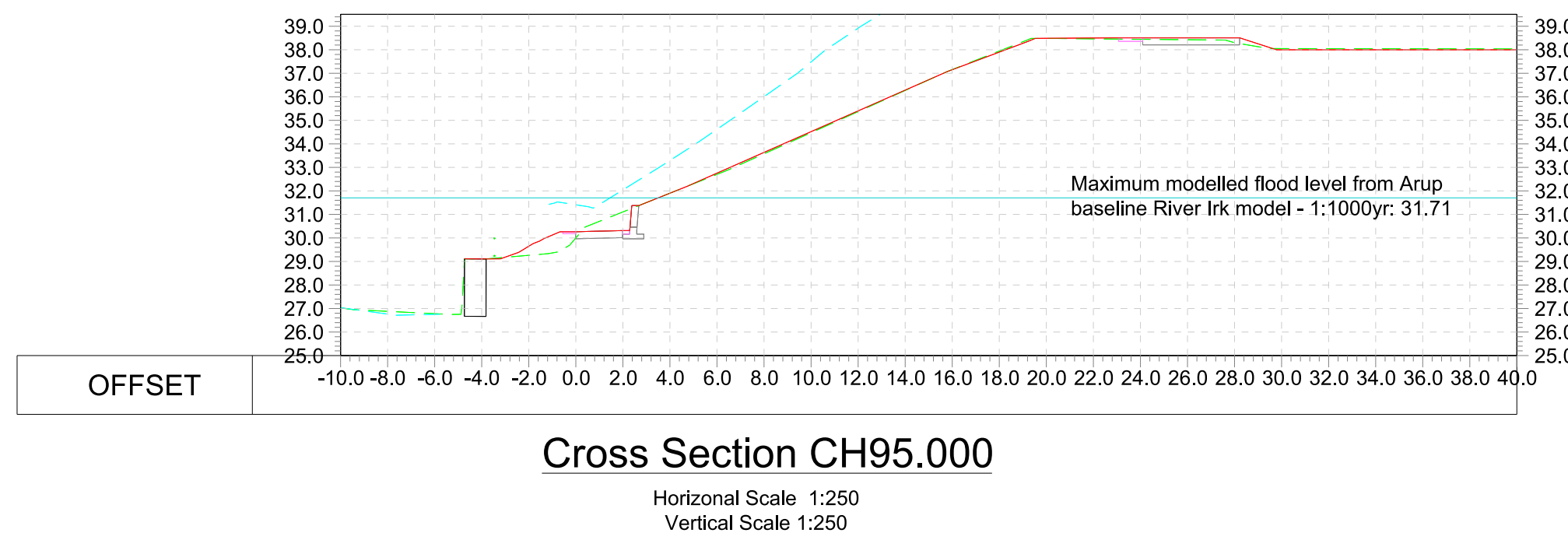
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Project Title
Victoria North HIF Infrastructure & Enabling Works

Drawing Title
Proposed Riverside Footpath
Cross Sections
Sheet 1 of 4

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Role Civil - Earth works and Geotechnics			
Suitability S3 - Issued for Review and Comment			
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6. This drawing is for coordination, it is not an installation drawing.

7. Maximum 1000yr Flood Level is based on the maximum of the existing and proposed modelled levels for nodes IRK_1.06 and IRK_1.07 in VNIF-ARP-ZZ-RIV-RP-DF-0002.

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9. Refer to Geotechnical Interpretive Report VNIF-ARP-ZZ-YYY-RP-CG-0012 P03 for ground parameters.

10. For SHE box hazards and risks see general arrangement drawing VNIF-ARP-ZZ-YYY-DR-CE-0020.

11. Retaining wall sections are shown indicatively on this drawing. Refer to Drawing CS-0024 for detailed wall sections.

Key

Proposed riverside footpath with verge and indicative retaining wall. Retaining wall is to be Redi-Rock blocks, or similar approved, as agreed in principle with the EA

— — — — — Existing Terrain

— — — — — Pre-development Terrain

Proposed Terrain

Proposed Railing

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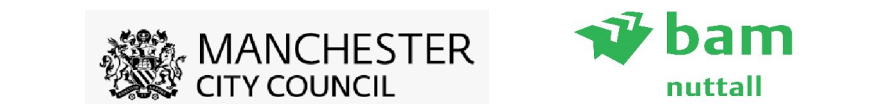
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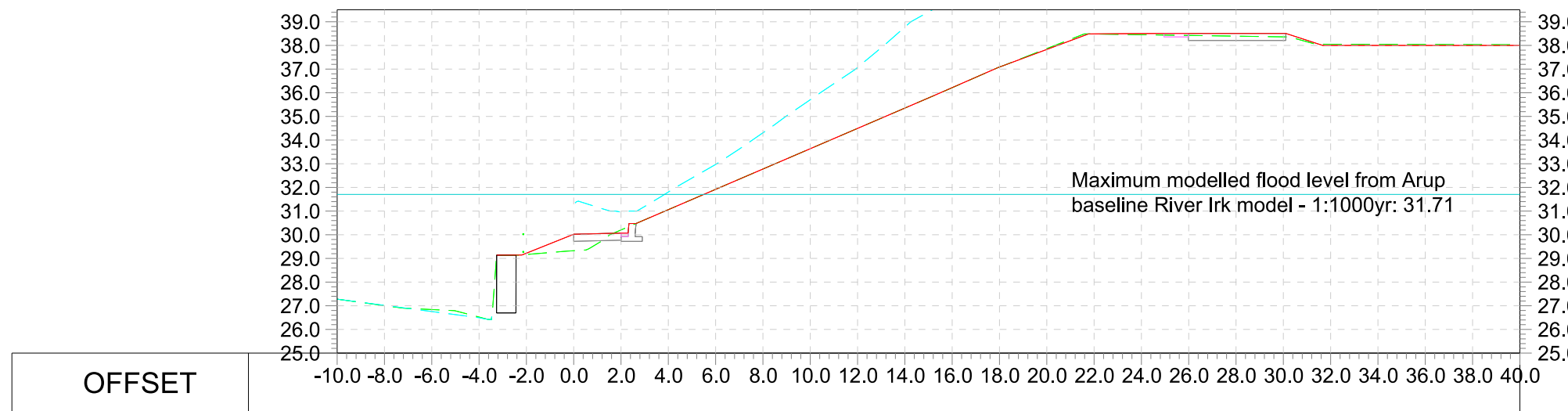
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Proposed Riverside Footpath

Cross Sections

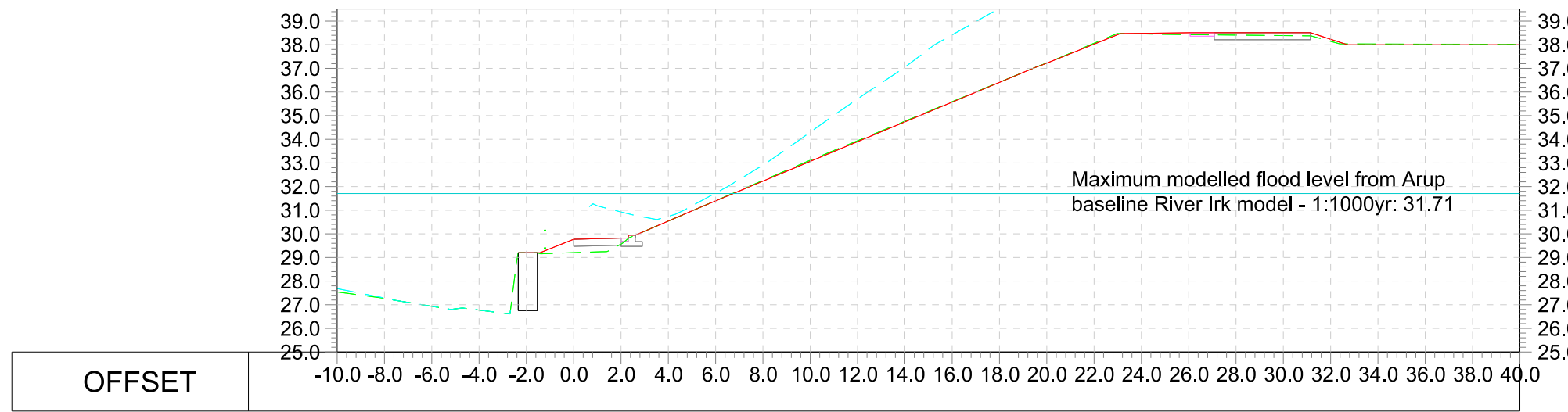
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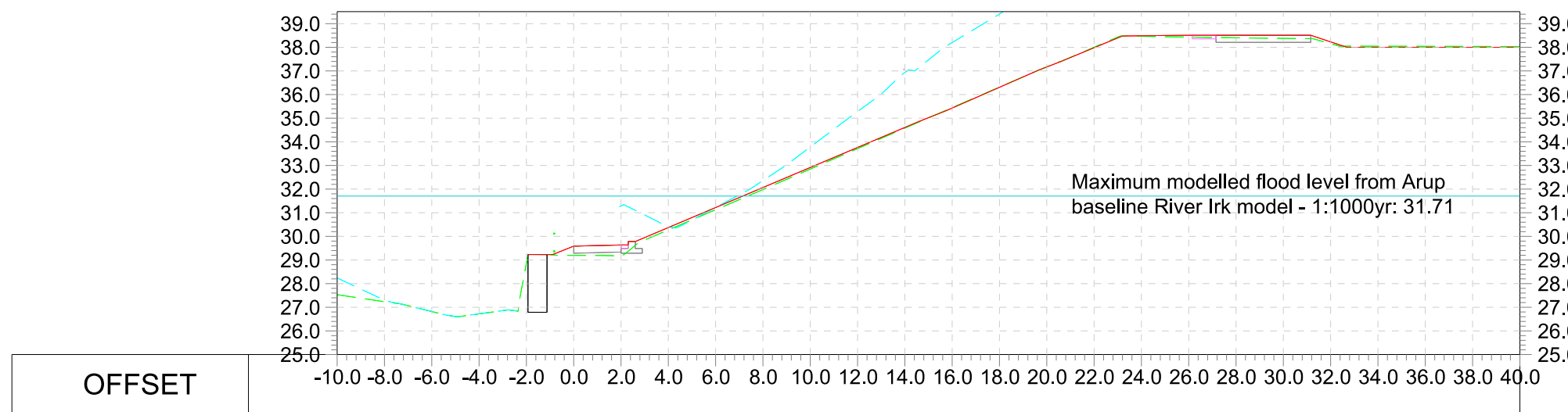
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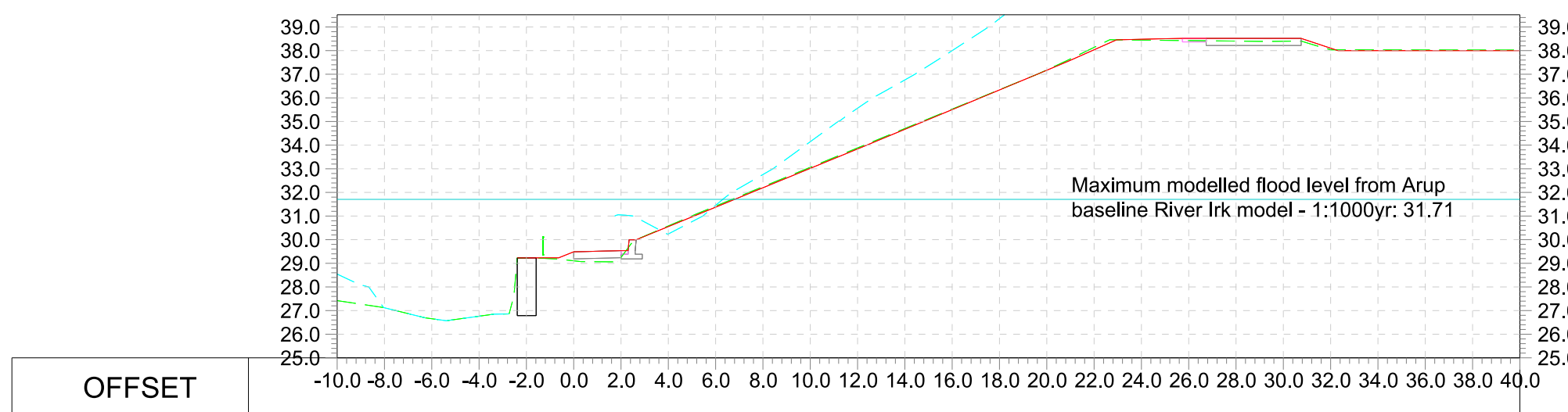
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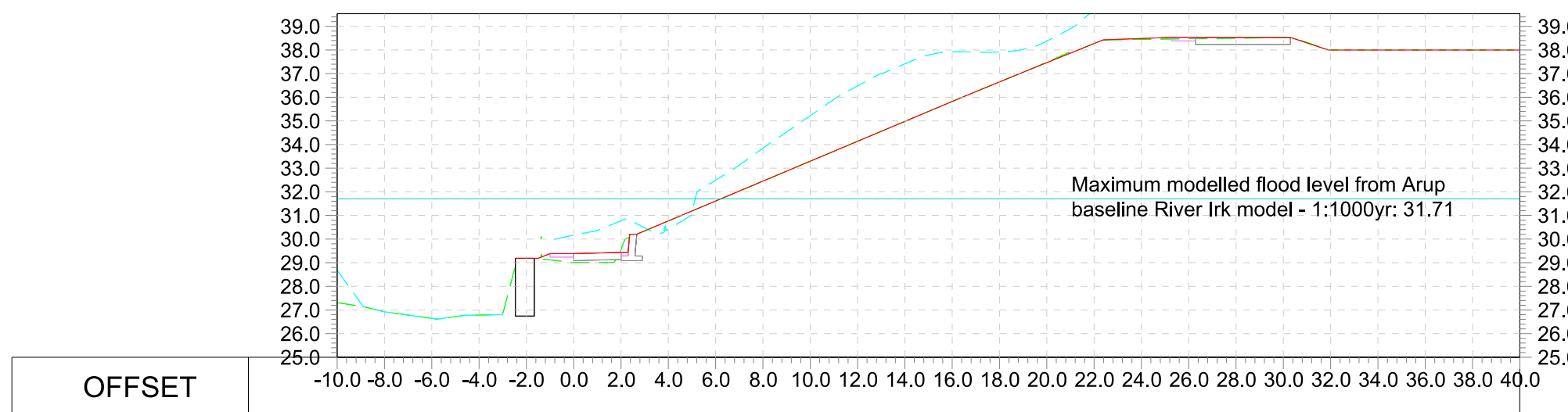
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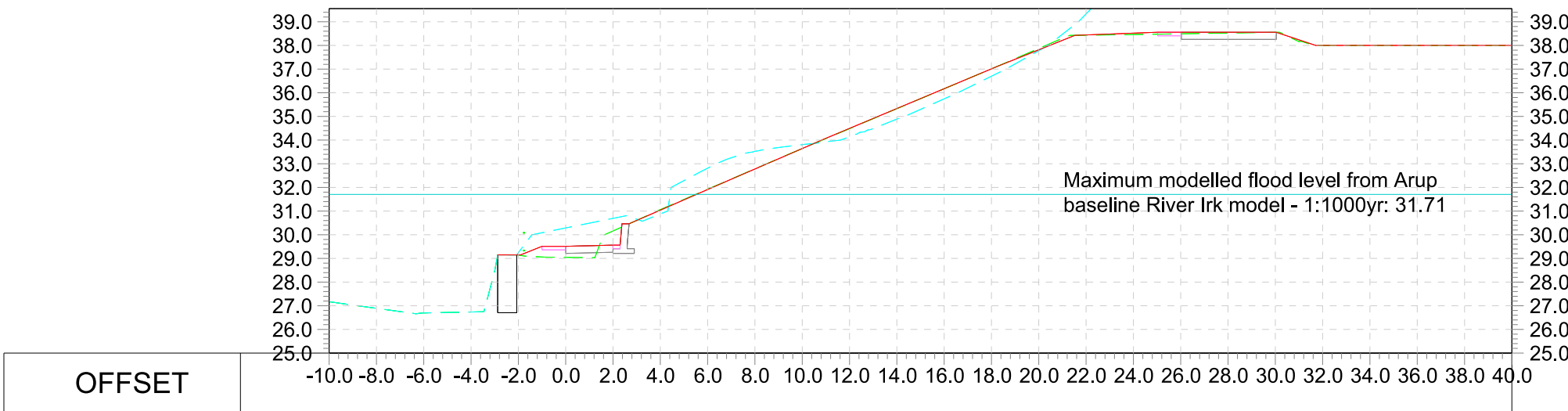
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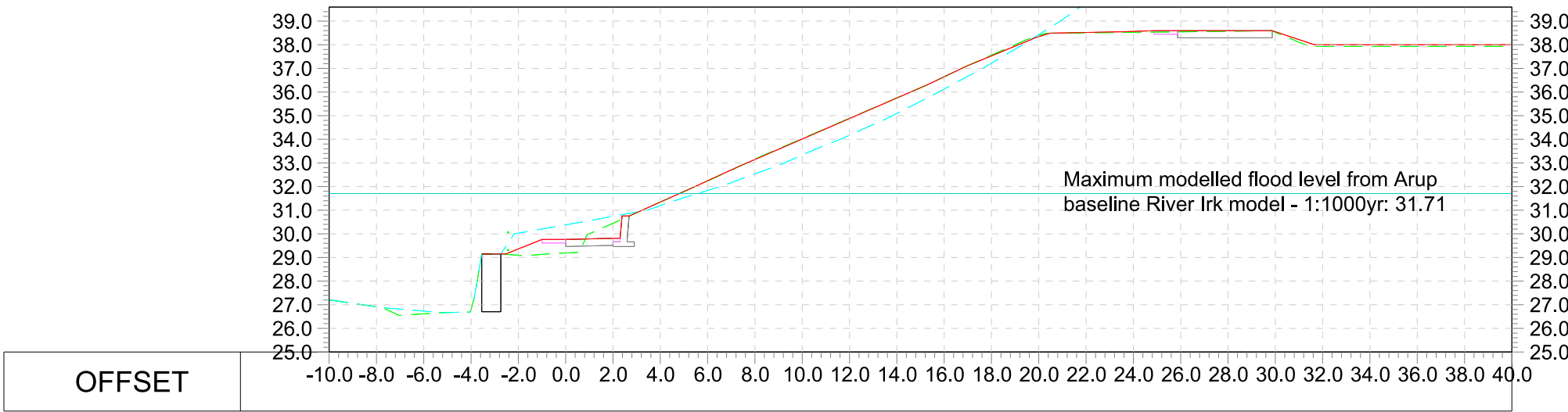
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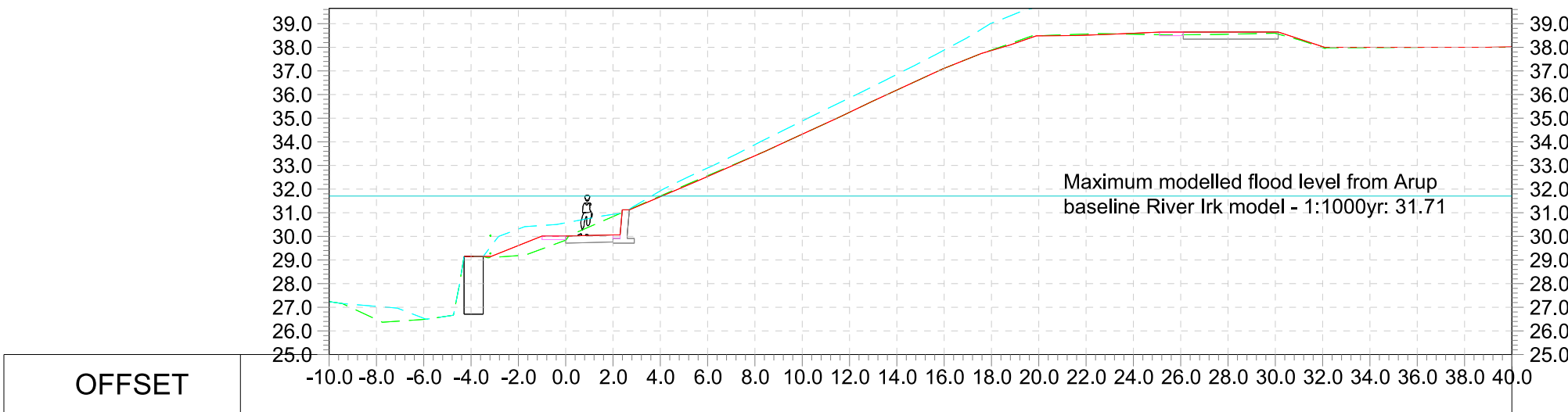
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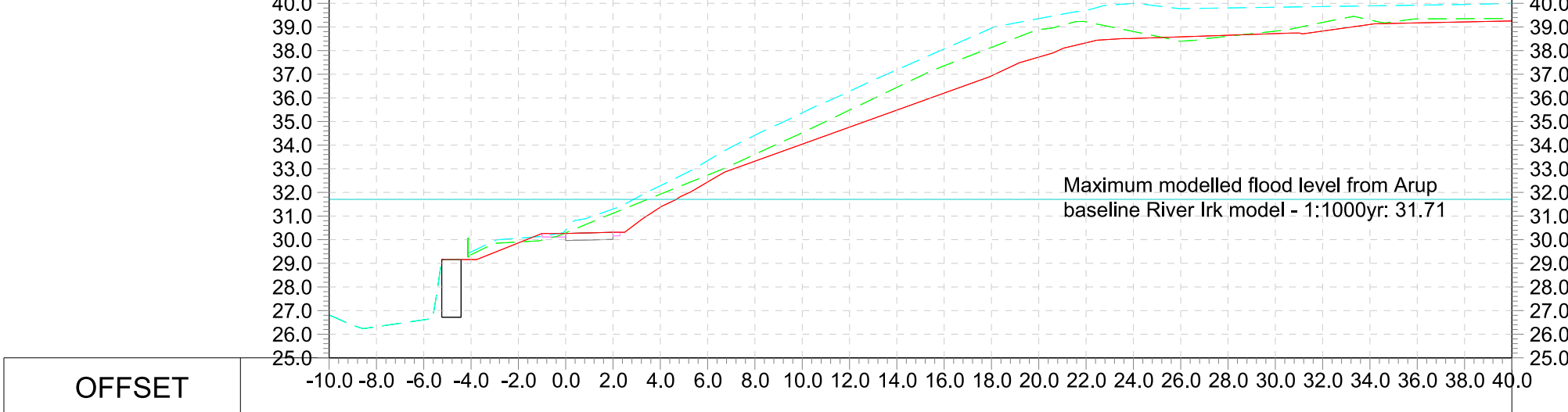
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Cross Section CH145.000

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Key

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- Pre-development Terrain
- Proposed Terrain
- Proposed Railing
- Existing River Wall

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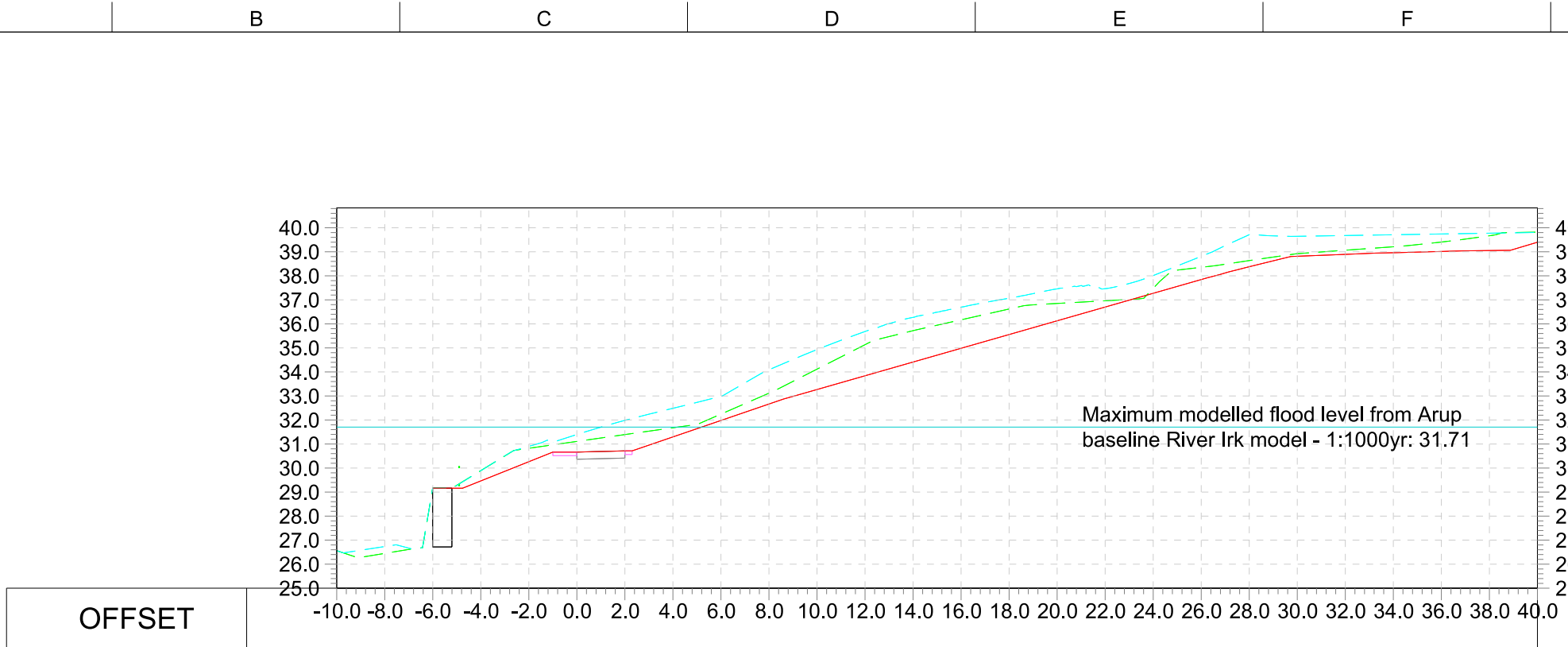


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Victoria North HIF Infrastructure & Enabling Works

Drawing Title
Proposed Riverside Footpath
Cross Sections
Sheet 3 of 4

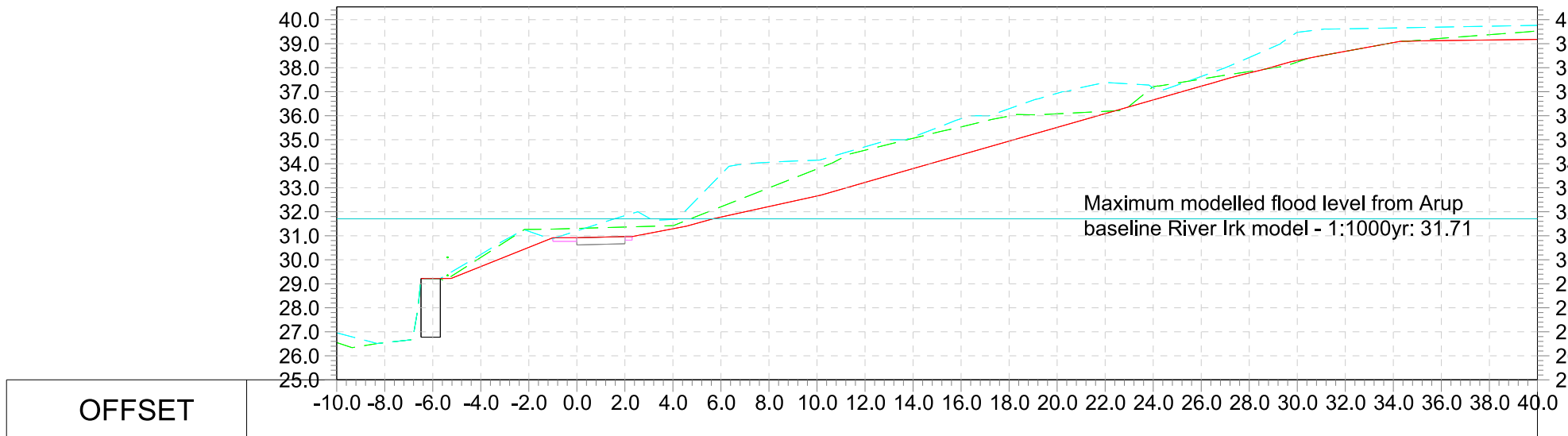
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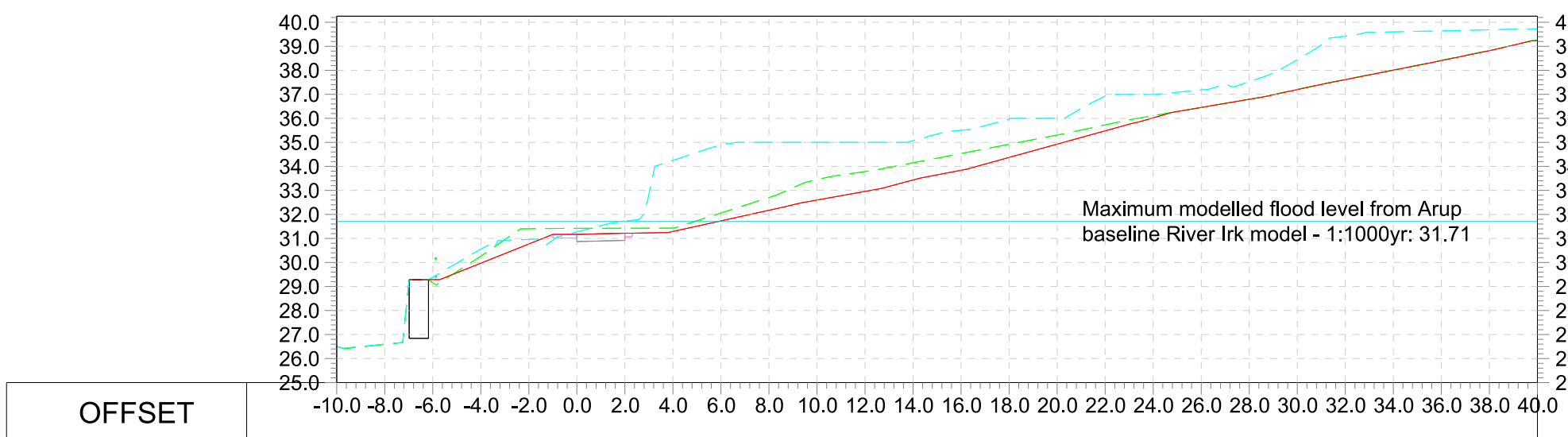
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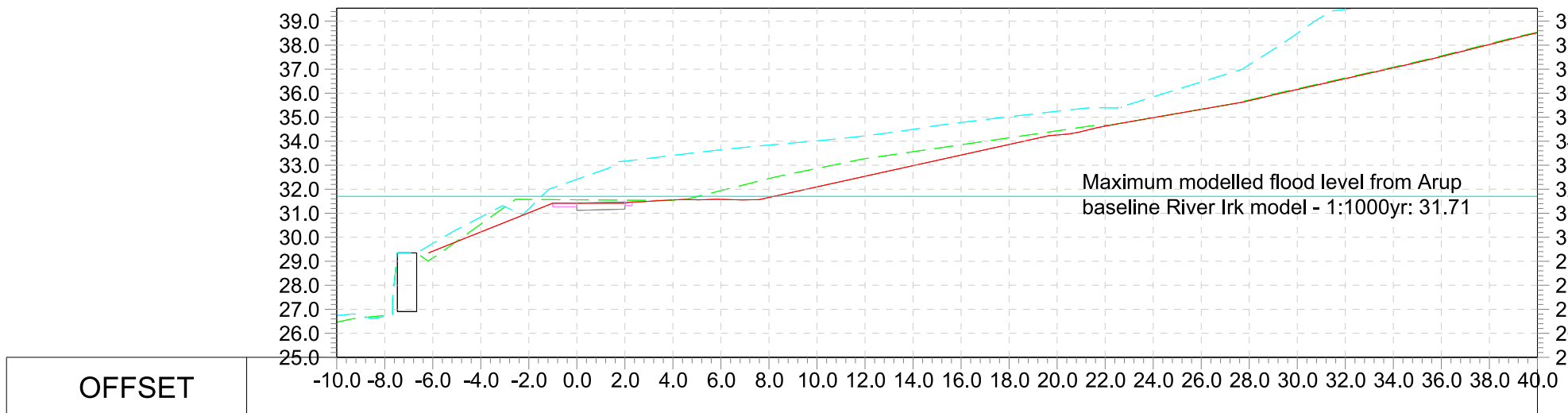
Cross Section CH155.000

Horizontal Scale 1:250
Vertical Scale 1:250



Cross Section CH160.000

Horizontal Scale 1:250
Vertical Scale 1:250



Cross Section CH165.000

Horizontal Scale 1:250
Vertical Scale 1:250

Notes

1. All dimensions are in mm, all levels in mAOD, unless specified otherwise.
2. This map is reproduced from Ordnance Survey Material with the permission of the Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office (c) Crown Copyright. License Number 100019568 (2025).
3. Sections are based on:
 - Topographical Survey drawing PS-2158-TS by Paragon Surveys dated September 2021.
 - Topographical Survey by Bam dated 24/02/2025.
4. Drawing to be read in conjunction with the Victoria North HIF Infrastructure Works, Earthworks Specification, ref VNIF-ARP-ZZ-YYY-SP-CG-0004.
5. Refer to drawing VNIF-ARP-ZZ-YYY-DR-CE-0020 for cross section locations.
6. This drawing is for coordination, it is not an installation drawing.
7. Maximum 1000yr Flood Level is based on the maximum of the existing and proposed modelled levels for nodes IRK_1.06 and IRK_1.07 in VNIF-ARP-ZZ-RIV-RP-DF-0002.
8. Live load surcharge behind retaining structures shall be limited to 5kPa (characteristic).
9. Refer to Geotechnical Interpretive Report VNIF-ARP-ZZ-YYY-RP-CG-0012 P03 for ground parameters.
10. For SHE box hazards and risks see general arrangement drawing VNIF-ARP-ZZ-YYY-DR-CE-0020.
11. Retaining wall sections are shown indicatively on this drawing. Refer to Drawing CS-0024 for detailed wall sections.

Key

-  Proposed riverside footpath with verge and indicative retaining wall. Retaining wall is to be Redi-Rock blocks, or similar approved, as agreed in principle with the EA
-  Existing Terrain
-  Pre-development Terrain
-  Proposed Terrain
-  Proposed Railing
-  Existing River Wall

P01	20/06/25	First Issue	AS	ES	GL	—
P02	30/09/25	River Wall Design for Review	AS	ES	GL	—
Rev	Date	Description	By	Chkd	Appd	Auth

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Project Title
Victoria North HIF Infrastructure & Enabling Works

Drawing Title
Proposed Riverside Footpath
Cross Sections
Sheet 4 of 4

Scale at A1			AS SHOWN		Arup Job No		282022-00	
Role		Civil - Earth works and Geotechnics						
Suitability		S3 - Issued for Review and Comment						
Rev	By	AS	Chkd	ES	Appd	GL	---	
	P02	Date	30/09/25		Date	30/09/25		---
		Date	30/09/25		Date	30/09/25		
Name								
VNIF		- ARP - ZZ - YYY - DR - CE - 0024						
Project	Originator	Volume	Location	Type	Role	Number		

A1

A

B

C

D

E

F

G

H

I

J

K

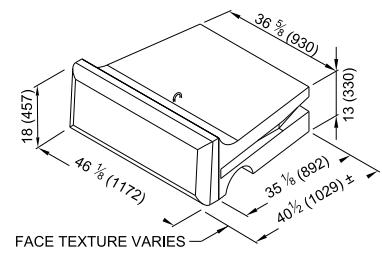
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M

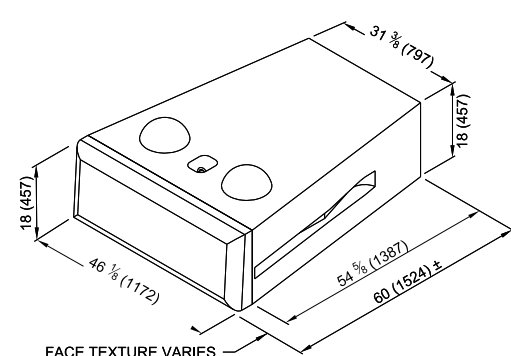
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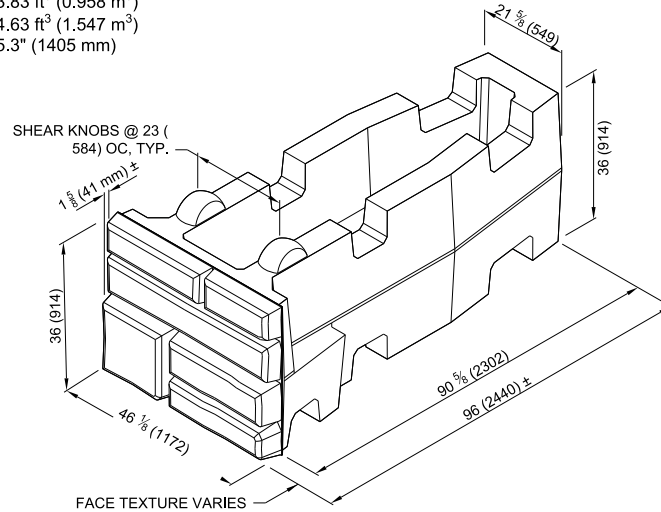
R-41T 41" (1030mm) TOP *
Face Texture: Cobble / Limestone Kingstone / Ledgestone
Block Weight: 1750 lb (790 kg) 1680 lb (760 kg)
Block Volume: 12.22 ft³ (0.346 m³) 11.73 ft³ (0.332 m³)
Center of Gravity: 21.3" (540 mm) 20.8" (522 mm)



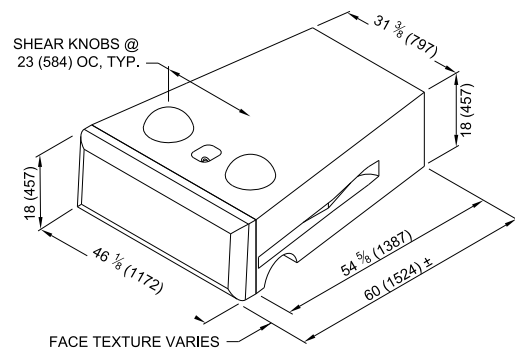
R-60B 60" (1520mm) BOTTOM
Face Texture: Cobble / Limestone Kingstone / Ledgestone
Block Weight: 3420 lb (1550 kg) 3350 lb (1520 kg)
Block Volume: 23.90 ft³ (0.677 m³) 23.40 ft³ (0.665 m³)
Center of Gravity: 31.8" (802 mm) 31.0" (788 mm)



R-9636HC 96" (2440 mm) XL Hollow-Core
Face Texture: Ledgestone
Block Weight: 4840 lb (2190 kg)
Block Volume: 33.83 ft³ (0.958 m³)
Infill Volume: 54.63 ft³ (1.547 m³)
Center of Gravity: 55.3" (1405 mm)



R-60M 60" (1520mm) MIDDLE
Face Texture: Cobble / Limestone Kingstone / Ledgestone
Block Weight: 3280 lb (1480 kg) 3220 lb (1460 kg)
Block Volume: 23.00 ft³ (0.651 m³) 22.48 ft³ (0.637 m³)
Center of Gravity: 31.0" (788 mm) 30.4" (772 mm)



Redi-Rock Blocks

Scale 1:50

Block Notes

- Units for dimensions are inches (mm), typical unless noted otherwise.
- Block production varies with each licensed Redi-Rock manufacturer. Confirm availability before Specifying or Ordering.
- Centre of Gravity is measured from the back of block, excluding stone infill.
- Actual block volumes and weights may vary.
- Weights are based upon a concrete density of 143 lb/ft (2291kg/m³).
- Interface Shear knobs are nominally 10" (254mm) diameter by 4" (102 mm) tall. Smaller knob diameters are available.
- Hollow blocks to be filled with "FND3" mix concrete in accordance with BS 8500-2:2023. *NB - Possible opportunity to cast weepholes in void prior to infill.*

General Notes Continued

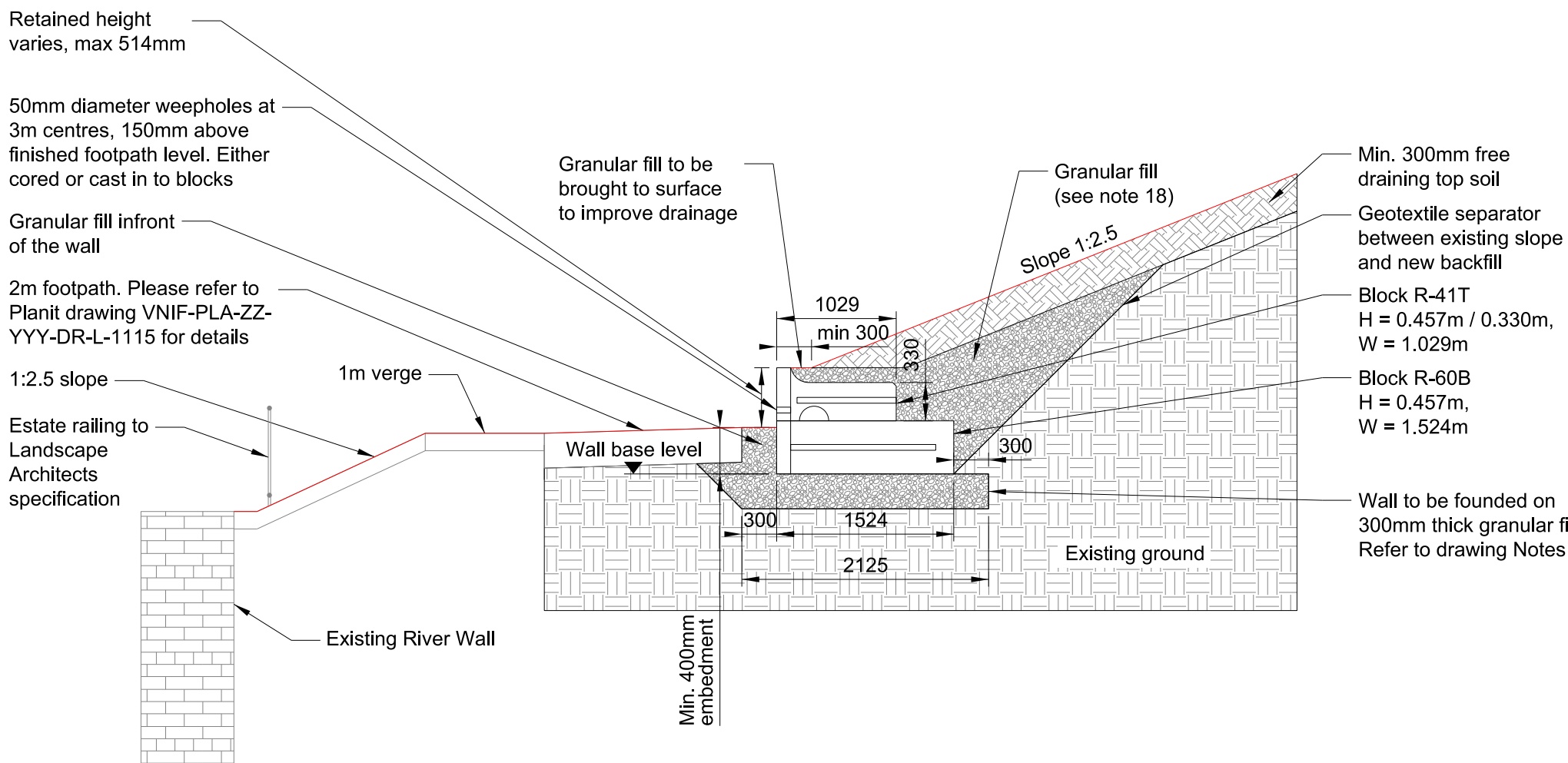
- Consult statutory utility plans and the utility and drainage surveys for details of buried utilities and services. Use a CAT scanner prior to excavation.
- Foundation preparation - the final 300mm of excavation shall be made using a flat toothless bucket to minimise disturbance of the formation level. Formation to be proof-rolled to identify soft spots. Proof-rolling and definition of soft-spots to be in accordance with the relevant sections of Clause 6/7.2 of the Specification (ref VNIF-ARP-ZZ-YYY-SP-C-0001). Soft spot treatment is also to be undertaken in accordance with Clause 6/7.2 of the Specification. The relevant sections of CI 6/7.2 are as follows:
 - The proof-rolling shall consist of at least two passes of a smooth-wheeled vibratory roller having a minimum mass per metre roll width of 2100 kg, or other suitable method agreed with the Project Manager.
 - A minimum undrained shear strength value of 50 kN/m² is required across the sub-formation in cohesive soils and soil stiffness greater than 2% CBR is required at sub-formation level in granular soils. Should soft spots be identified that do not meet these requirements, their lateral extent shall be determined by inspection and additional testing as appropriate and is to be recorded on as-built drawings.
 - Soft spots each with an area in plan of no more than 100 square metres and extending no more than 1m below sub-formation level shall be excavated and backfilled using Class 1 or Class 2 general fill or other acceptable fill materials.
 - For soft areas each with an area in plan of larger than 100 square metres or deeper than 1m below sub-formation level, the Contractor is to agree the treatment with the Project Manager.
 - On completion of proof-rolling and soft-spot treatment, a programme of testing is to be undertaken to validate the geotechnical properties of the sub-formation against the requirements set out in Appendix 1/5.
- Contamination in excavation: if visual or olfactory evidence suggests the potential for contamination, contact the contract administrator for further advice before disturbing the material further.
- Base layer to be Type 1 subbase compacted in accordance with Series 800 of the specification for highways works.
- Redi-Rock blocks to be installed in accordance with manufacturers instructions.
- Backfilling in front of the wall to be completed before commencing backfill behind the wall.
- Backfill material to be class 6N/6P placed in accordance with series 600 of the Specification for Highways Works. The design assumes a drained shear strength (ϕ') of 42 degrees. Contractor to undertake large shear box testing to validate this at a minimum of 3 tests per source.
- Unless otherwise stated, all materials arising from the site clearance or foundation excavation work which are surplus to, or unacceptable for use in the permanent works shall become the property of the contractor and shall be disposed of off site.
- Any proposed amendments to the wall design by the supplier shall be submitted for Arup acceptance prior to construction.

General Notes

- All dimensions are in mm, all levels in mAOD, unless specified otherwise.
- This drawing is to be read in conjunction with Arup Highways and Earthworks drawings and Plantit Landscaping drawings VNIF-PLA-ZZ-YYY-DR-L-3004.
- Earthwork materials to be in accordance with the earthworks specification, part of the wider project specification VNIF-ARP-ZZ-YYY-SP-C-0001.
- Retaining wall assumed to consist of Redi-Rock pre-cast blocks, with limestone textured finish. The temporary case and all lifting arrangements are to be determined by the contractor and pre-cast block supplier.
- Guardrail shown indicatively. Once a specific product has been selected, the Engineer is to be contacted to confirm appropriate fixing arrangement.
- 50mm weepholes at 3m centres to be provided along full length of wall. Weepholes to either be factory installed or cored on site.
- Existing soil properties anticipated to be generally medium dense granular made ground or firm gravely cohesive material.
- The design accounts for hydrostatic pressure at 2/3 height of the wall. Contractor to inform designer if seepage is seen at a higher level.
- Contractor to provide methodology and RAMS for the wall installation/or approval of contract administrator.
- For SHE box hazards and risks see general arrangement drawing VNIF-ARP-ZZ-YYY-DR-CE-0020.
- Ground conditions – contractor shall refer to factual reports:
 - AEG (2019) Northern Gateway Final Factual Report (Rev.00) NW1580
 - AEG (2021) Northern Gateway Phase 2 Final Factual Report (Rev.00) NW1604
 - BAM Richies (October 2022), Victoria North HIF Infrastructure & Enabling Works – Phase 3 GI Ground Investigation Report – Factual Account (Ref BAX.326R) (received 1st November 2022).

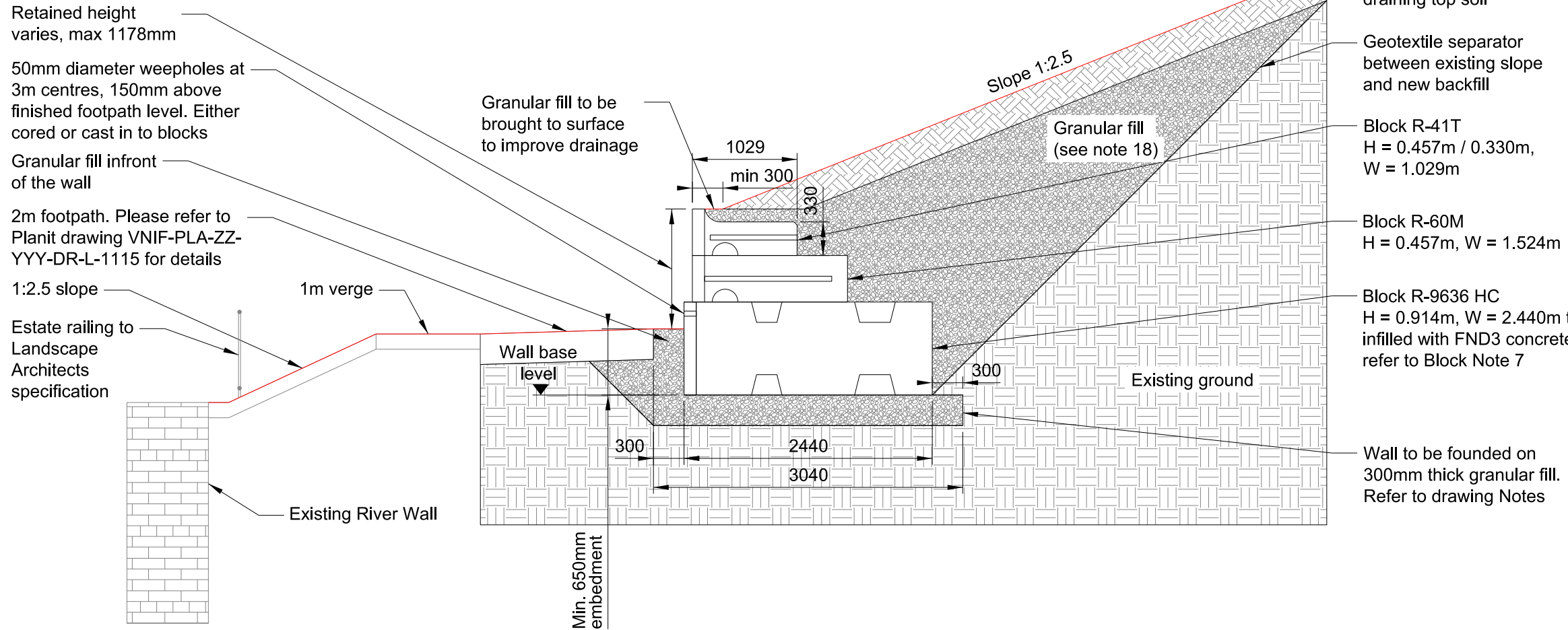
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Proposed Ground Level



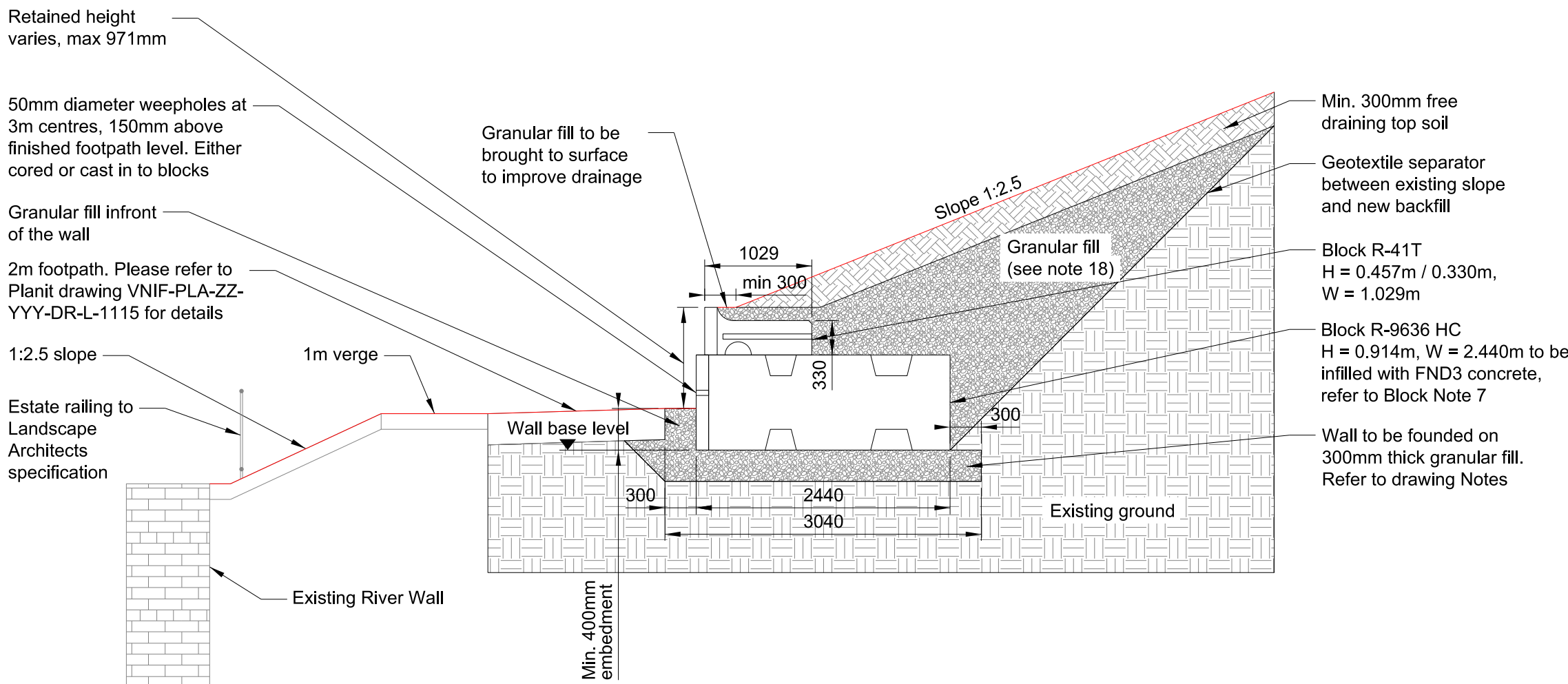
Wall Type W0.91

Scale 1:50



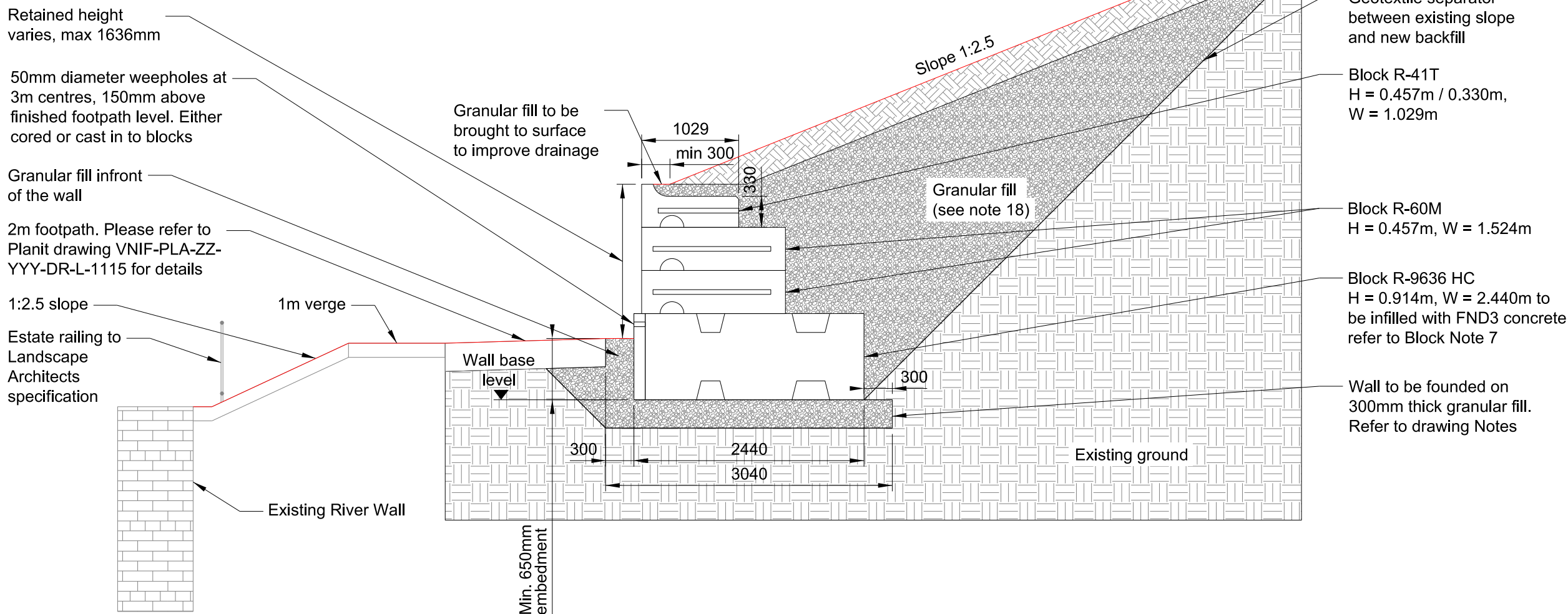
Wall Type W1.83

Scale 1:50



Wall Type W1.37

Scale 1:50



Wall Type W2.29

Scale 1:50

P01	30/09/25	River Wall Design for Review	AS	ES	GL	---
Rev	Date	Description	By	Chkd	Appd	Auth

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Client



Project Title

Victoria North HIF Infrastructure & Enabling Works

Drawing Title

Riverwalk Footpath Retaining Wall
Sections

Scale at A1 1:50 Arup Job No 282022-00

Role Structural Engineers

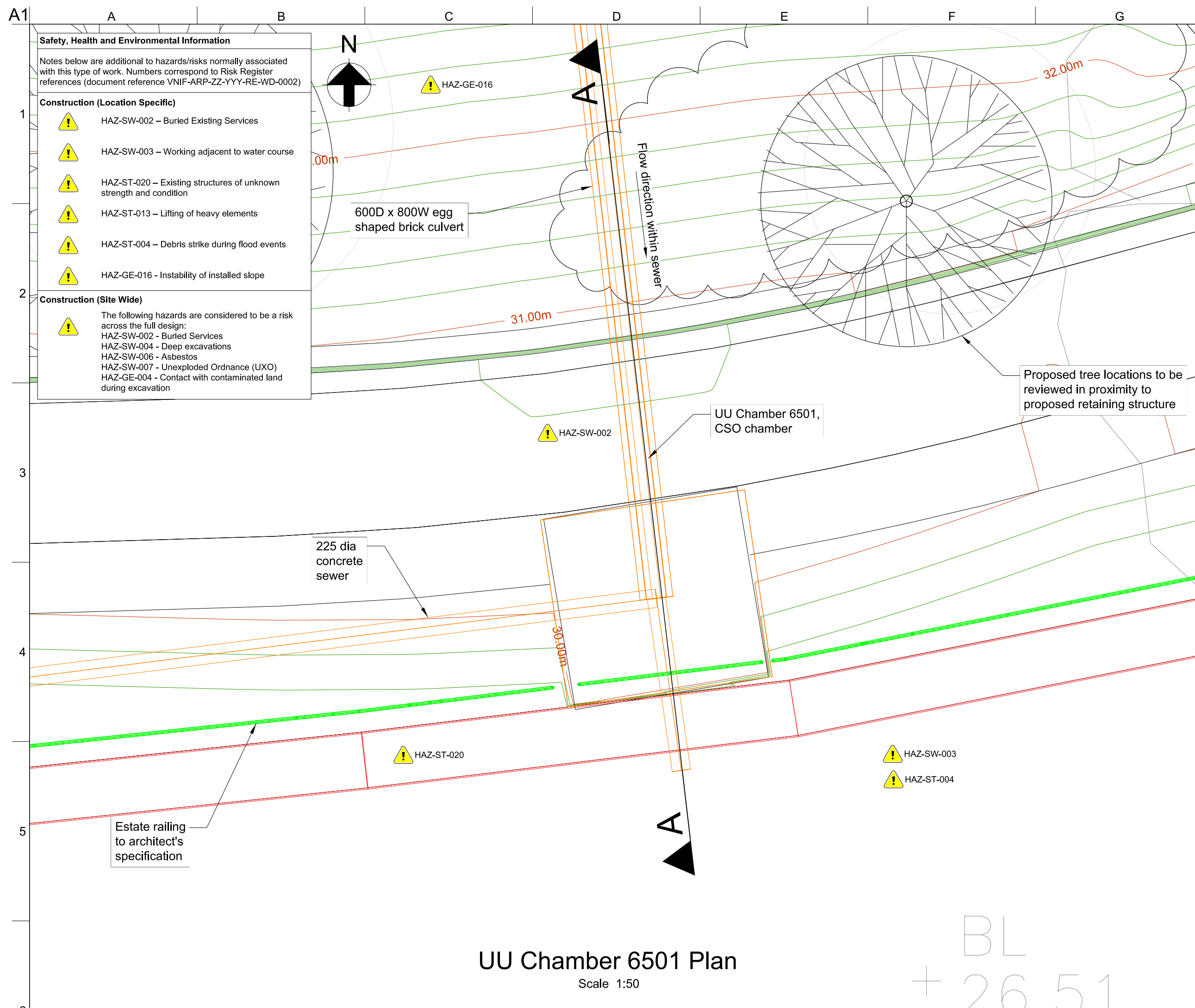
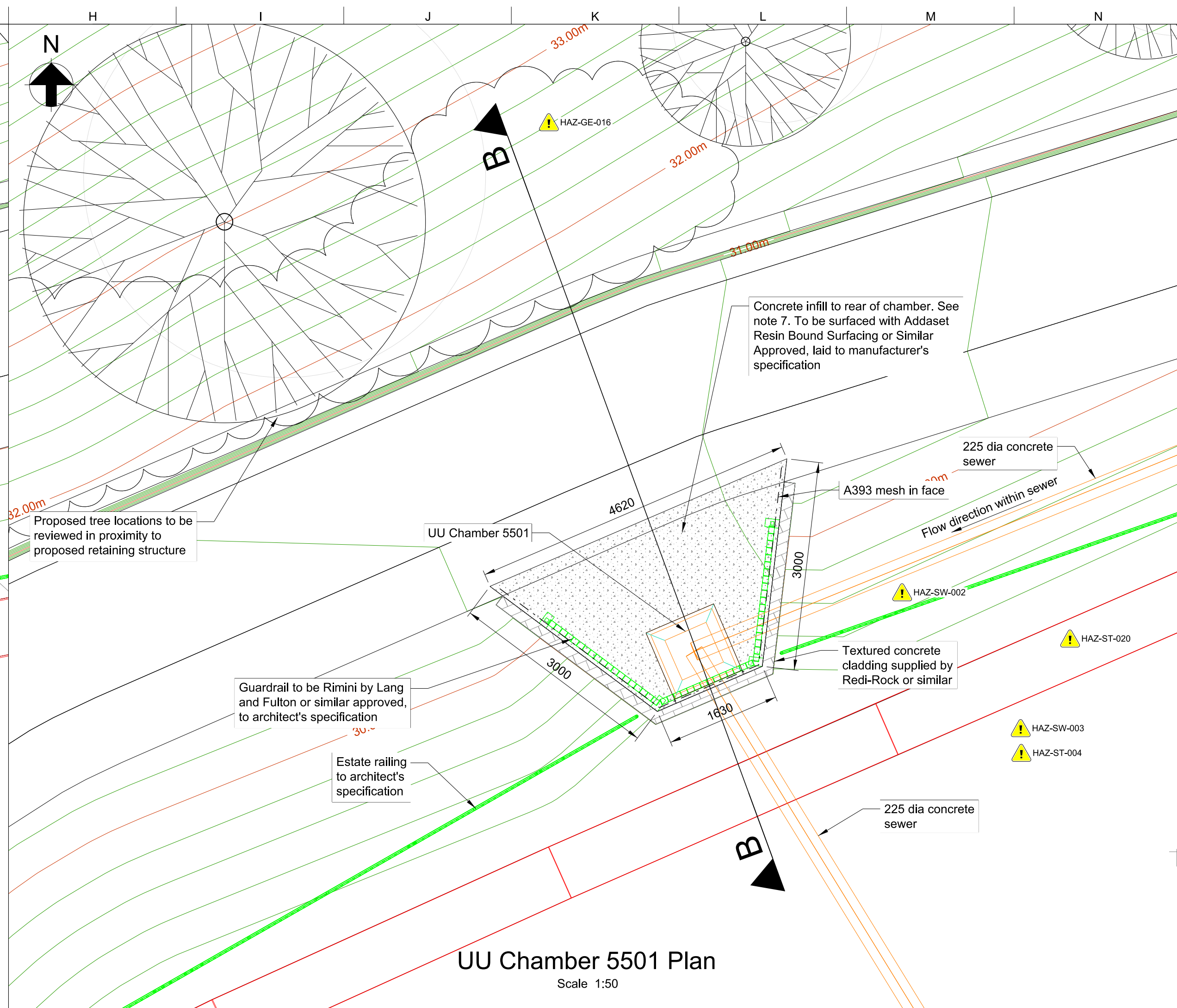
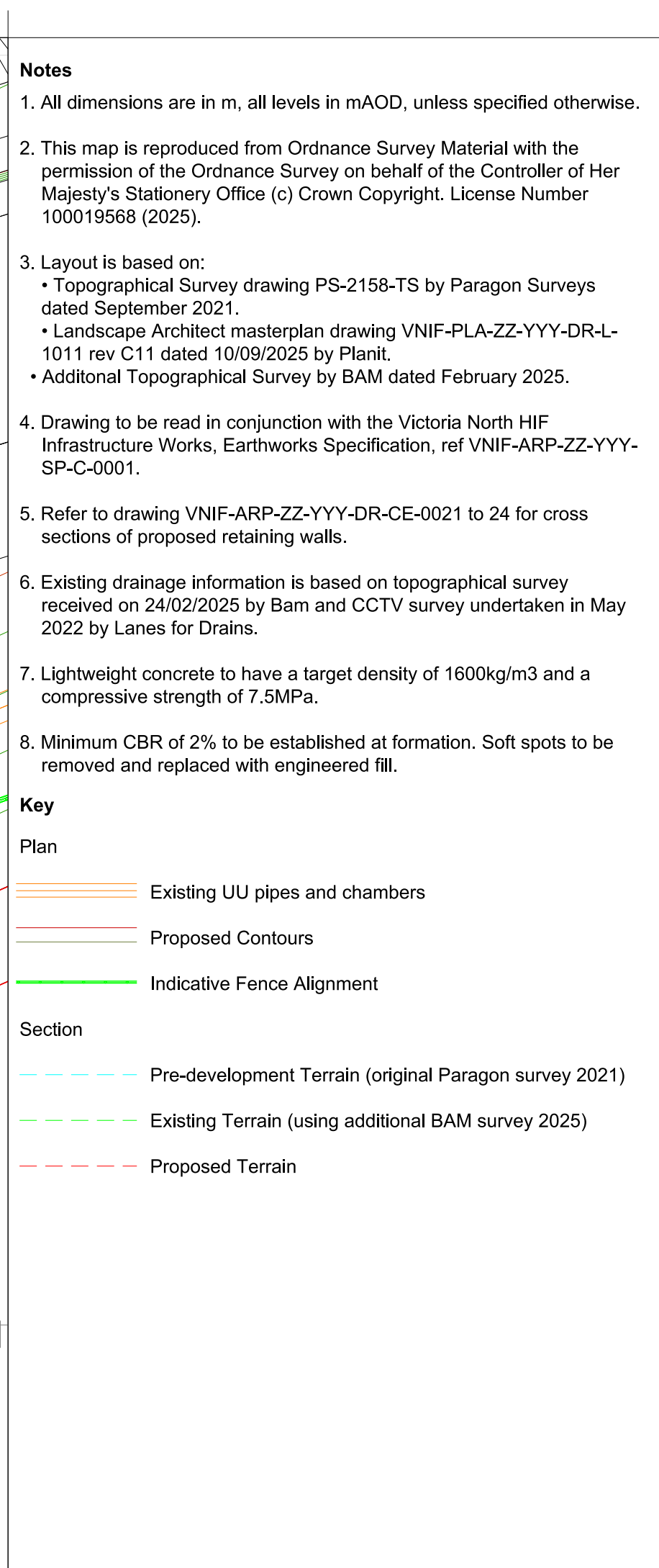
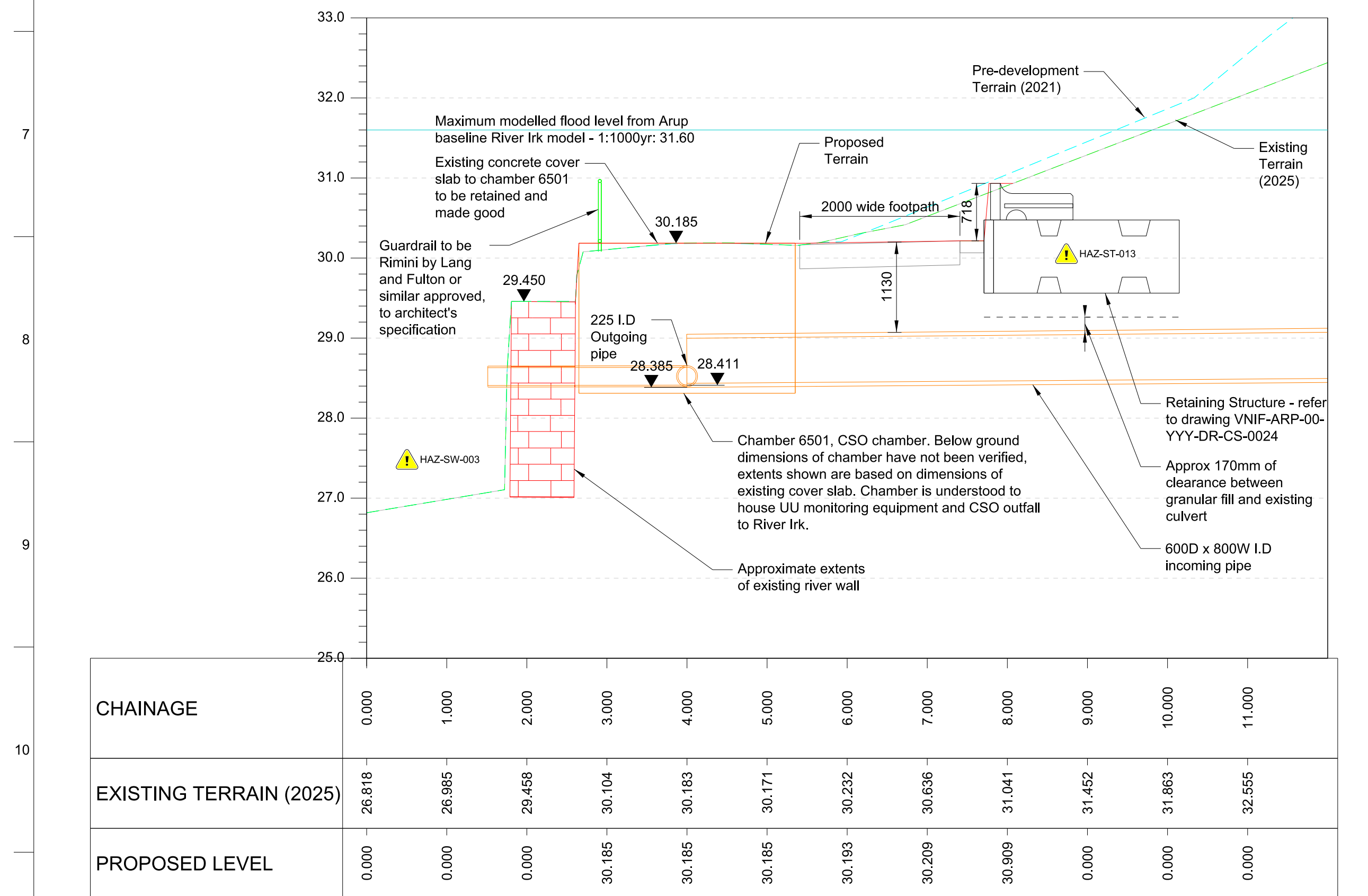
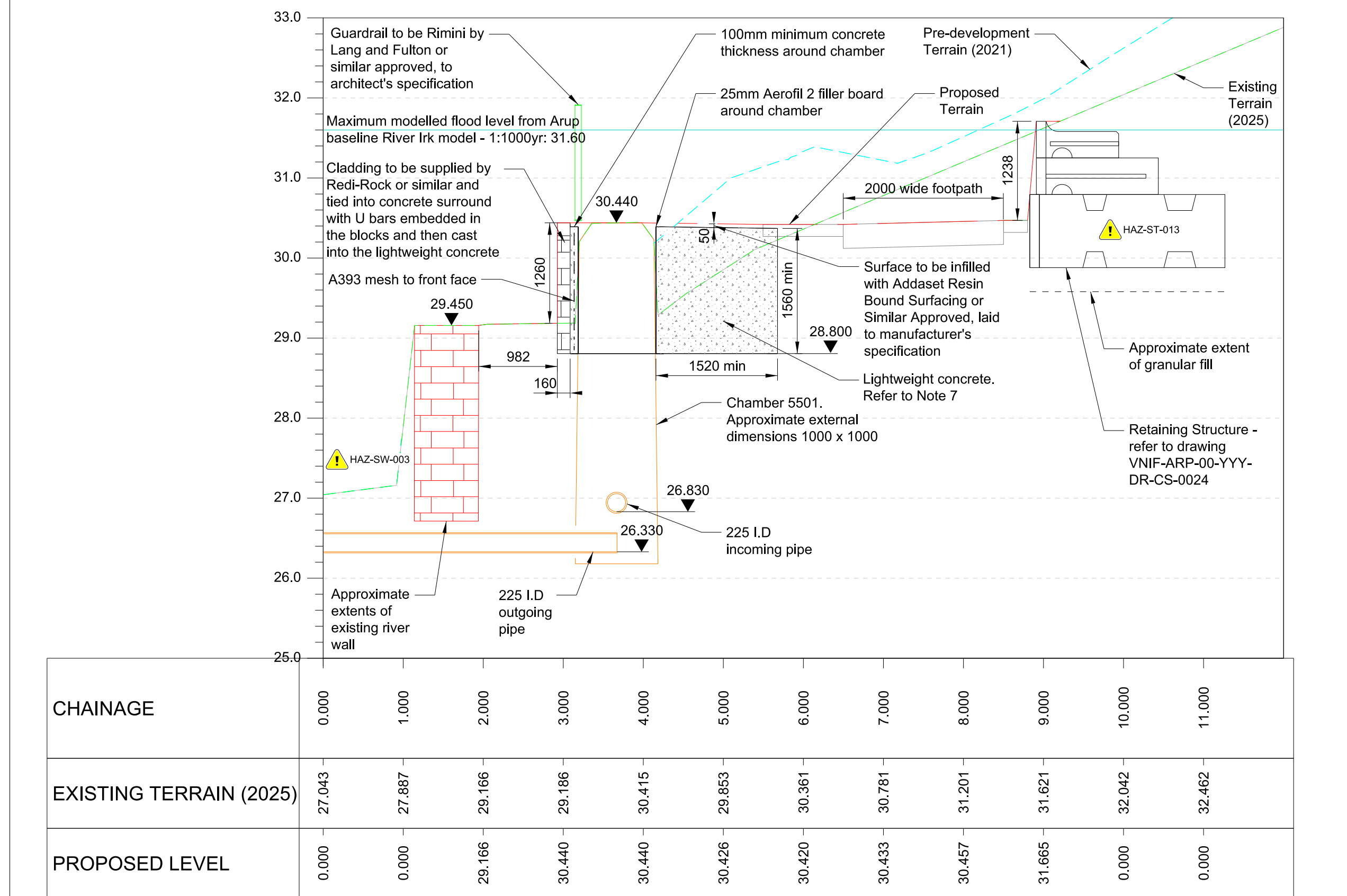
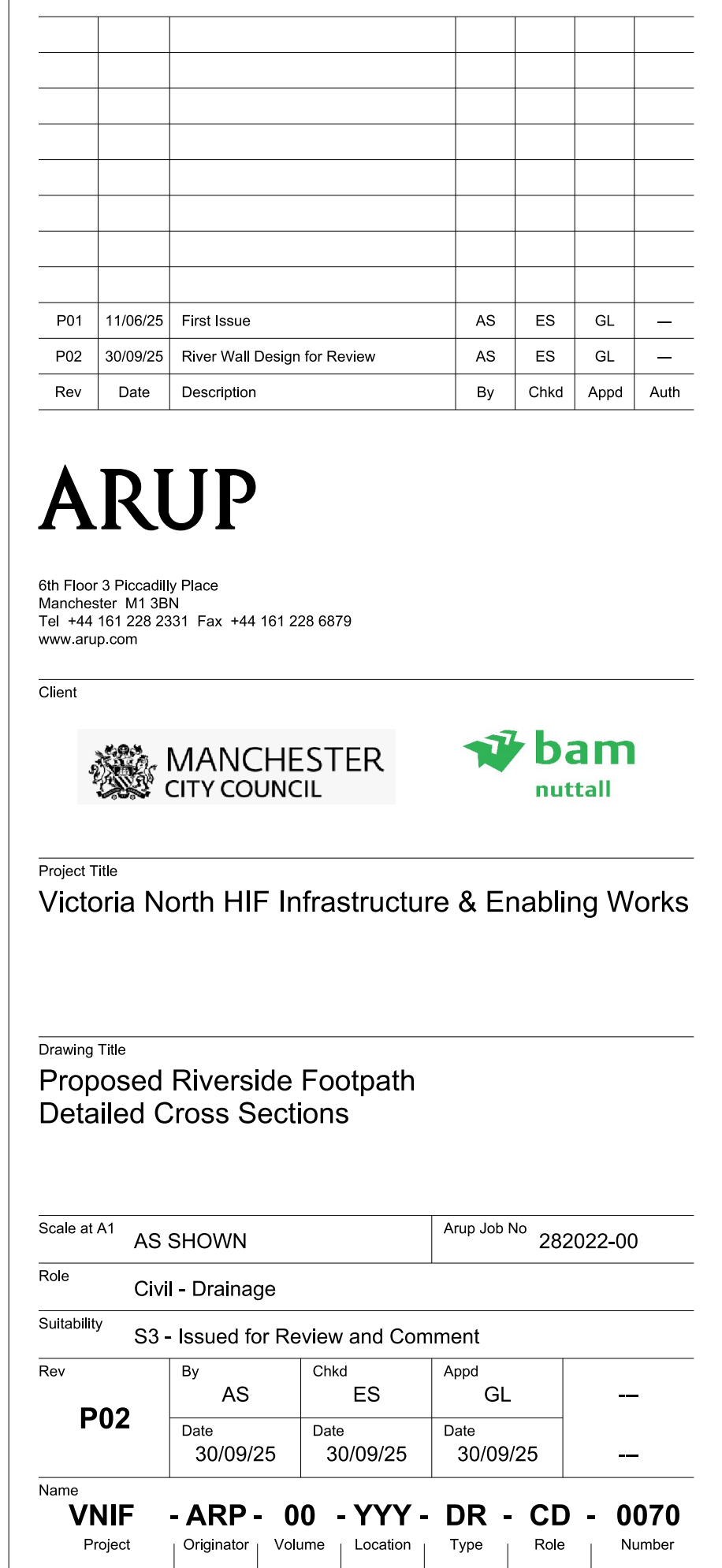
Suitability S3 - Issued for Review and Comment

Rev	By	AS	Chkd	ES	Appd	GL	---
P01	Date	30/09/25	Date	30/09/25	Date	30/09/25	---

Name

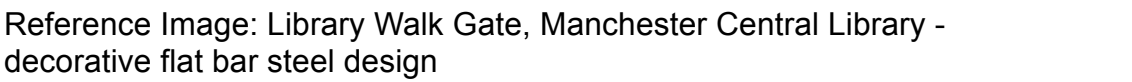
VNIF - ARP - 00 - YYY - DR - CS - 0024

Project Originator Volume Location Type Role Number



Appendix C St Catherine's Wood Bridge Drawings

Scale at A1 As Shown				Plant-IE Job No 2700			
Role Landscape Architect							
Suitability S4							
Rev	By YH	Chkd MS	Appd GB				
P01	Date 29.08.25	Date 29.08.25	Date 29.08.25				
Name VNIF-PLA-ZZ-YYY-SK-L-8029							
Project VNIF	Originator PLA	Volume ZZ	Location YYY	Type DR	Role L	Number 8029	

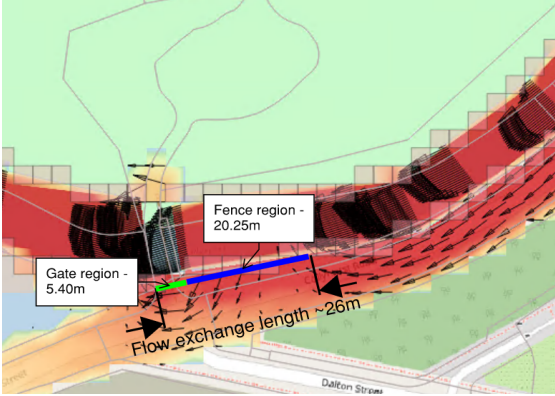


1 Gate & Fence Detail - fully closed
Scale: 1:25

<div>ARUP</div>		Job No.	Sheet No.	Rev.
		282022		1
		Member/Location		
Job Title	Victoria North	Drg. Ref.		
Calculation	SCW Gate Void Area Calc	Made by	TK	Date 16/09/2025 Chd. ES

Based on the Arup 2022 Baseline hydraulic model, flow is observed out-of bank, travelling south-west along Collyhurst Road. Flow exchange is then observed along a portion of the left bank of the lrk which includes the location of the proposed SCW gate. This purpose of this calculation is to demonstrate the relative change in void area along this length between the existing and proposed case.

The length over which the calculation has been applied is the observed length from the 2022 baseline maodel where flow exchange occurs between in-channel and out-of-channel flows, this has been measured at approximately 26m from the hydraulic model:



1. Existing Fence Void Area

Measured parameters (mm):	
1.a Length of fence (based on topo)	20247
1.b Length of single fence panel (Bam measured)	2800
1.c Bars per panel (Bam measured)	21
1.d Width of fence bars (Bam measured)	20
1.e Height of bars (Bam measured)	1300

Calculated parameters:	
1.f Spacing of bar centres (mm b/c	133
1.g Number of bars a/f	152
1.h Area of fence region (m2) a*e	26.3

Solid bar area at selected depths:

	Flood depth (mm)	Total Area at depth (m2)	Solid Area (m2)
1.i	100	2.025	0.304
1.j	480	9.719	1.458
1.k	1380	27.941	3.948

Area of voids (m2)	ref	calc ref
1.721	1.i	(i*a) - (d*g*i)
8.261	1.m	(j*a) - (d*g*j)
23.993	1.n	(e*a) - (d*g*k)

2. Existing Gate (vehicle barrier) Void Area

The existing vehicle barrier is made up of a number of vertical, horizontal and diagonal bars:



2.a Width of existing gate bars (measured from topo)	0.15 m
2.b Total width of gate (from topo)	5.4 m

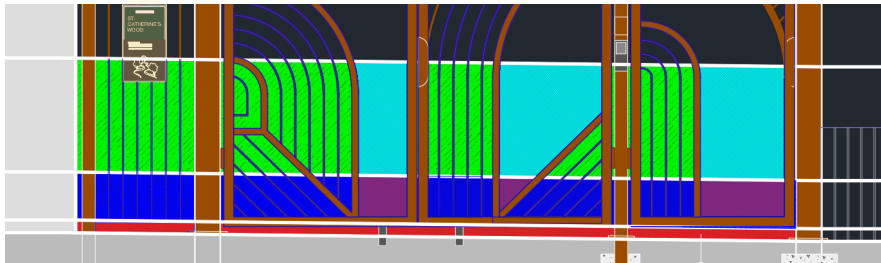
Bar Areas:			
	Gate bar	Length,m (topo)	Area (m2)
2.c	Vertical 1	0.8	0.12
2.d	Horizontal	3.9	0.58
2.e	Vertical 2	0.7	0.11
2.f	Vertical 3	0.8	0.12
2.g	Diagonal	2.0	0.30
2.h	Total		1.23

Gate Areas:						
	Flood depth(m)	Bars included	Total area at depth (m2)	Solid Area (m2)	Area of voids	ref
2.i	0.1	2.c, 2.e, 2.f	0.540	0.045	0.495	2.l
2.j	0.48	2.c, 2.e, 2.f, 2.g	2.592	0.288	2.304	2.m
2.k	1.38	2.c, 2.d, 2.e, 2.f, 2.g	7.452	1.229	6.223	2.n

		Job No.	Sheet No.		Rev.
		282022		1	
Job Title		Member/Location			
Victoria North		Drg. Ref.			
Calculation	SCW Gate Void Area Calc	Made by	TK	Date	16/09/2025
		Chd.	ES		

3. Proposed Gate Void Area

Refer to drawing VNIF-PLA-ZZ-YYY-SK-L-8029 for proposed gate design
The proposed gate is split into the following areas:



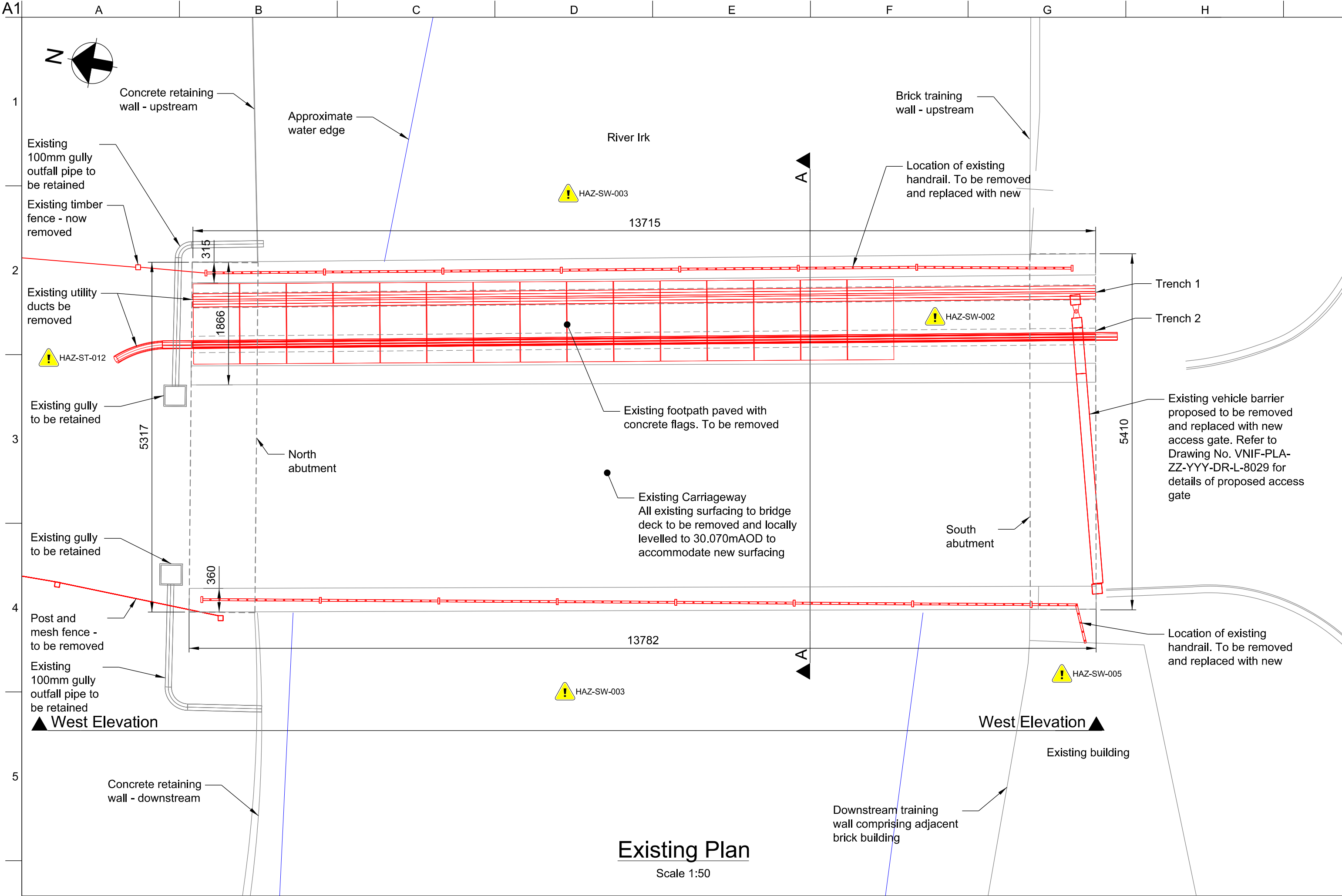
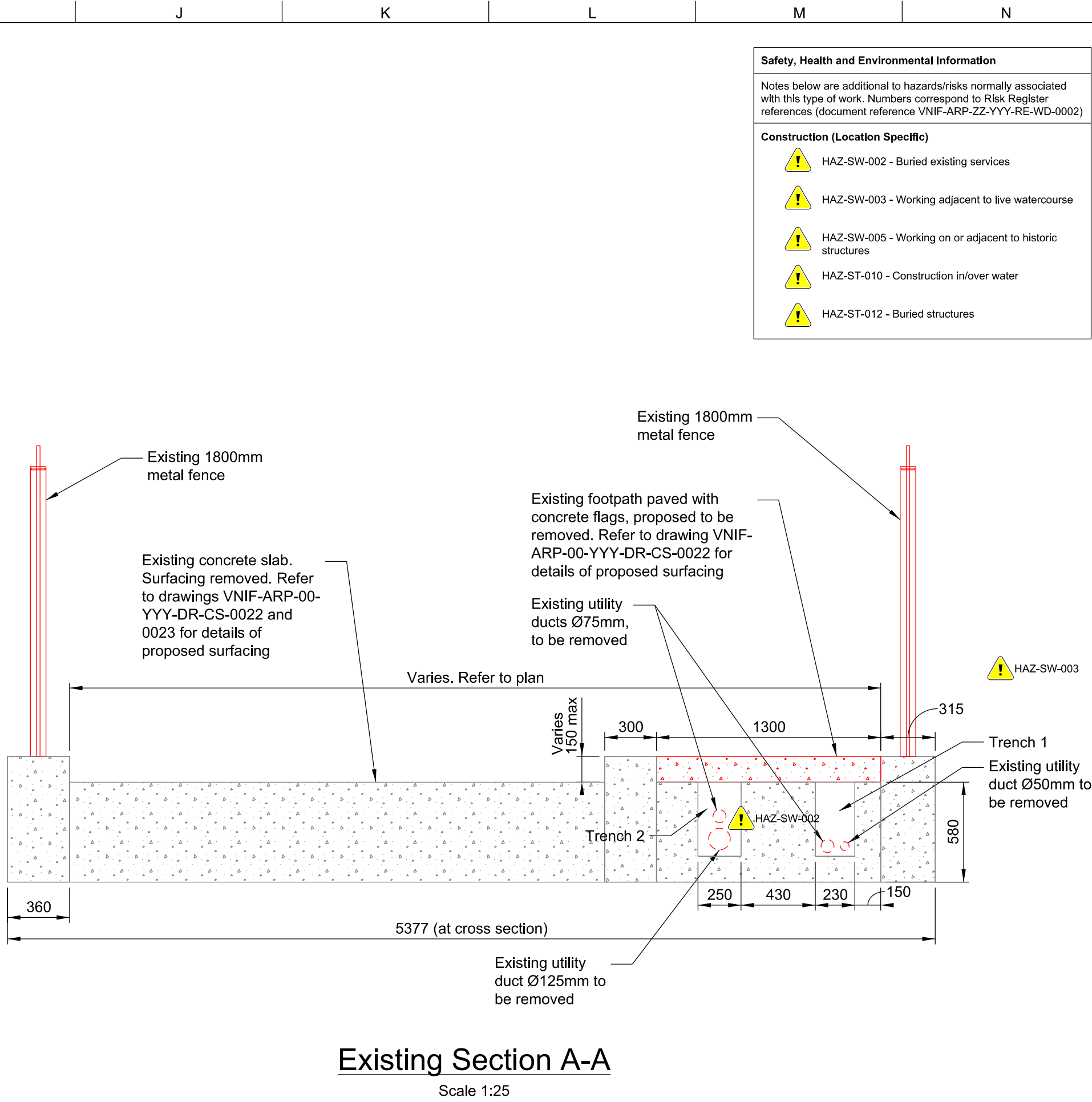
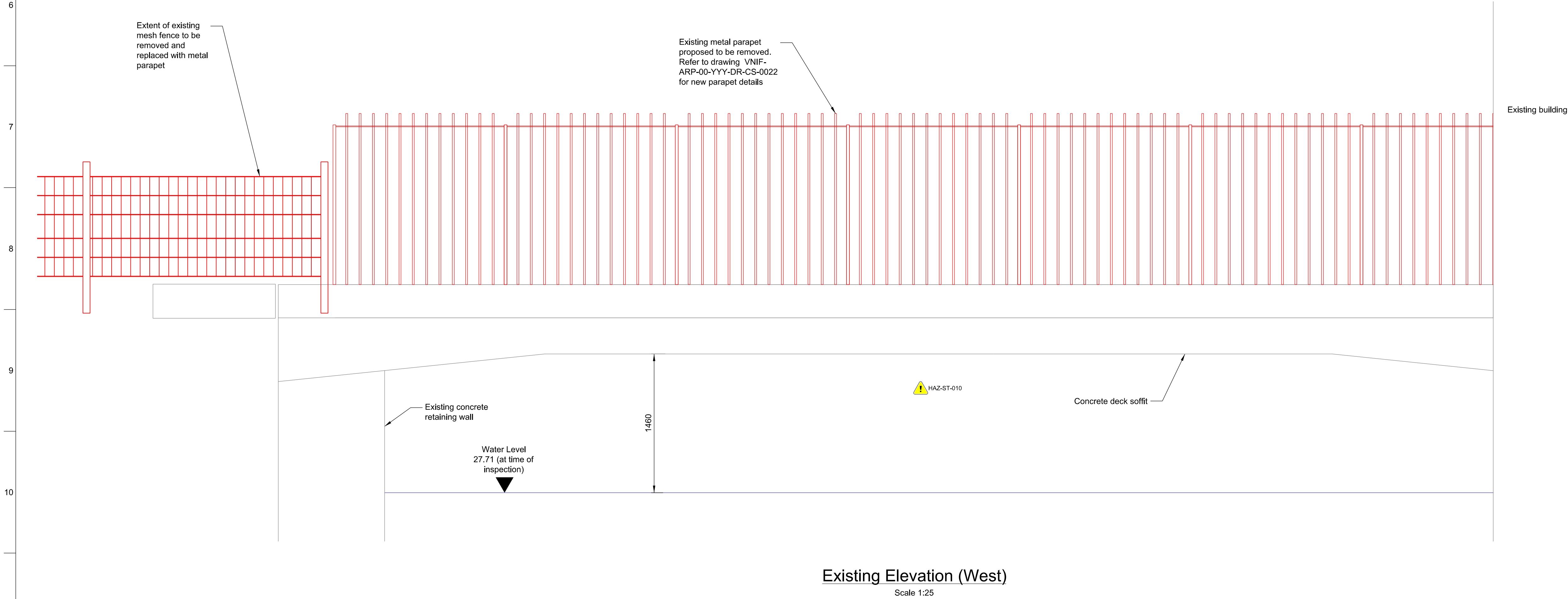
*The gate leaf pattern as sketched by the landscape architect is based on a reference image rather than a Cad design, the solid areas within portions of leaf pattern have therefore been approximated from the drawing

Flood depth range (m)	Type	Colour (see image above)	Leaf Area* (m)	Void Area	ref	
0 - 0.1	Open Area	Red	n/a	0.433	3.a	Measured from Cad design
0.1 - 0.48	Open Area	Blue	n/a	1.021	3.b	Measured from Cad design
0.1 - 0.48	Leaf Pattern	Purple	0.262	0.092	3.c	
0.48 - 1.38	Open Area	Green	n/a	2.231	3.d	Measured from Cad design
0.48 - 1.39	Leaf Pattern	Cyan	0.785	0.722	3.e	

	Flood Depth (m)	Cumulative Void Area (m2)
3.f	0.1	0.433
3.g	0.48	1.546
3.h	1.38	4.499

4. Comparison of Void Area

	Void Area (m2)						
Flood Depth (m)	1. Existing Fence Region	2. Existing Gate Region	3. Proposed Gate Region	Total Existing	Total Proposed	Absolute Change	% change
0.1	1.721	0.495	0.433	2.22	2.15	0.06	2.8%
0.48	8.261	2.304	1.546	10.56	9.81	0.76	7.2%
1.38	23.993	6.223	4.499	30.22	28.49	1.72	5.7%



Safety, Health and Environmental Information	
Notes below are additional to hazards/risks normally associated with this type of work. Numbers correspond to Risk Register references (document reference VNIF-ARP-ZZ-YYY-RE-WD-0002)	
Construction (Location Specific)	
HAZ-SW-002 - Buried existing services	
HAZ-SW-003 - Working adjacent to live watercourse	
HAZ-SW-005 - Working on or adjacent to historic structures	
HAZ-ST-010 - Construction in/over water	
HAZ-ST-012 - Buried structures	

- Notes**
- All dimensions are in mm, all levels in mAOD, unless specified otherwise.
 - Layout is based on:
 - Topographical Survey drawing PS-2158-TS by Paragon Surveys dated September 2021.
 - Topographical Survey drawing 250711 SC Bridge Survey by BAM dated July 2025.
 - Dimensions shown are approximate and should be verified on site.
 - Existing metal parapet shown indicatively.
 - Refer to Drawing No. VNIF-ARP-00-YYY-DR-CS-0022 & 23 for proposed new parapet details.
 - Refer to Drawing No. VNIF-ARP-00-YYY-DR-CS-0020 & 21 for proposed repair details.

- Key**
- Proposed Removal
 - Existing Assets

P01	09/09/25	Issued for Technical Approval		AS	ES	GL	--
Rev	Date	Description	By	Chkd	Appd	Auth	

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Client



Project Title
Victoria North HIF Infrastructure & Enabling Works

Drawing Title
St. Catherine's Wood (Dalton footbridge)
Existing General Arrangement

Scale at A1				Anup Job No 282022-00										
Role		Structural Engineers												
Suitability		S3 - Issued for Review and Comment												
Rev	By	AS	Chkd	ES	Appd	GL	---							
								Date	08/09/25	Date	09/09/25	Date	09/09/25	---
Name														
VNIF		- ARP- 00 - YYY- DR - CS - 0019												
Project	Originator	Volume	Location	Type	Role	Number								



- Repair/removal type 1:**
- Repair of spalled and hollow sounding concrete**
1. Cut away all loose or deteriorated concrete until only sound concrete remains. Concrete to be cut back to at least 50mm beyond the end of corrosion on reinforcement and behind the bars. The edges must be cut squarely to avoid feathered edges during repair. Refer to Drawing No. VNIF-ARP-00-YYY-DR-CS-0021 for locations.
 2. Thoroughly clean all reinforcement to bright metal using emery paper, wire brushes, descaling pistols, grit blasting or similar technique. All debris to be collected.
 3. Apply a zinc rich cold galvanising coating such as Galvafruid by Fosroc or similar on the reinforcement to provide additional protection to the reinforcement.
 4. Place repair mortar Sika MonoTop-4100 or similar using hand placement techniques. The repair mortar shall be Class R4 in accordance with BS EN 1504-3.
 5. Minimum 20mm cover shall be maintained to be consistent with existing cover based on 2024 Inspection for Assessment Report (Reference No. PJ/SL07557).

Summary of Repair Areas:			
	Length (m)	Breadth (m)	Area (m²)
SP1	3.0	0.5	1.5
SP2	4.1	0.5	2.1
SP3	3.2	1.1	3.5
SP4	0.6	0.3	0.2
SP5	0.2	5.4	1.1
SP6	1.7	1.0	1.7
SP7	1.7	0.5	0.9
SP8	1.7	0.5	0.9
W3	0.5	0.5	0.3
W4	0.5	0.5	0.3
TOTAL			12.24

All repair areas are approximate and based on the findings of the 2024 structural examination.

The repair pricing shall be provided as a per s.q.m rate to allow for potential increase in repair area and additional locations.

SP - Spalling/hollow sounding area
W - Breakout window

- Notes**
1. All dimensions are in mm, all levels in mAOD, unless specified otherwise.
 2. This drawing is to be read in conjunction with VNIF-ARP-00-YYY-DR-CS-0021.
 3. The repair mortar shall be Class R4 in accordance with EN 1504-3.

P01	22/08/25	Issued for Technical Approval		AS	AM	ES	—
Rev	Date	Description		By	Chkd	Appd	Auth

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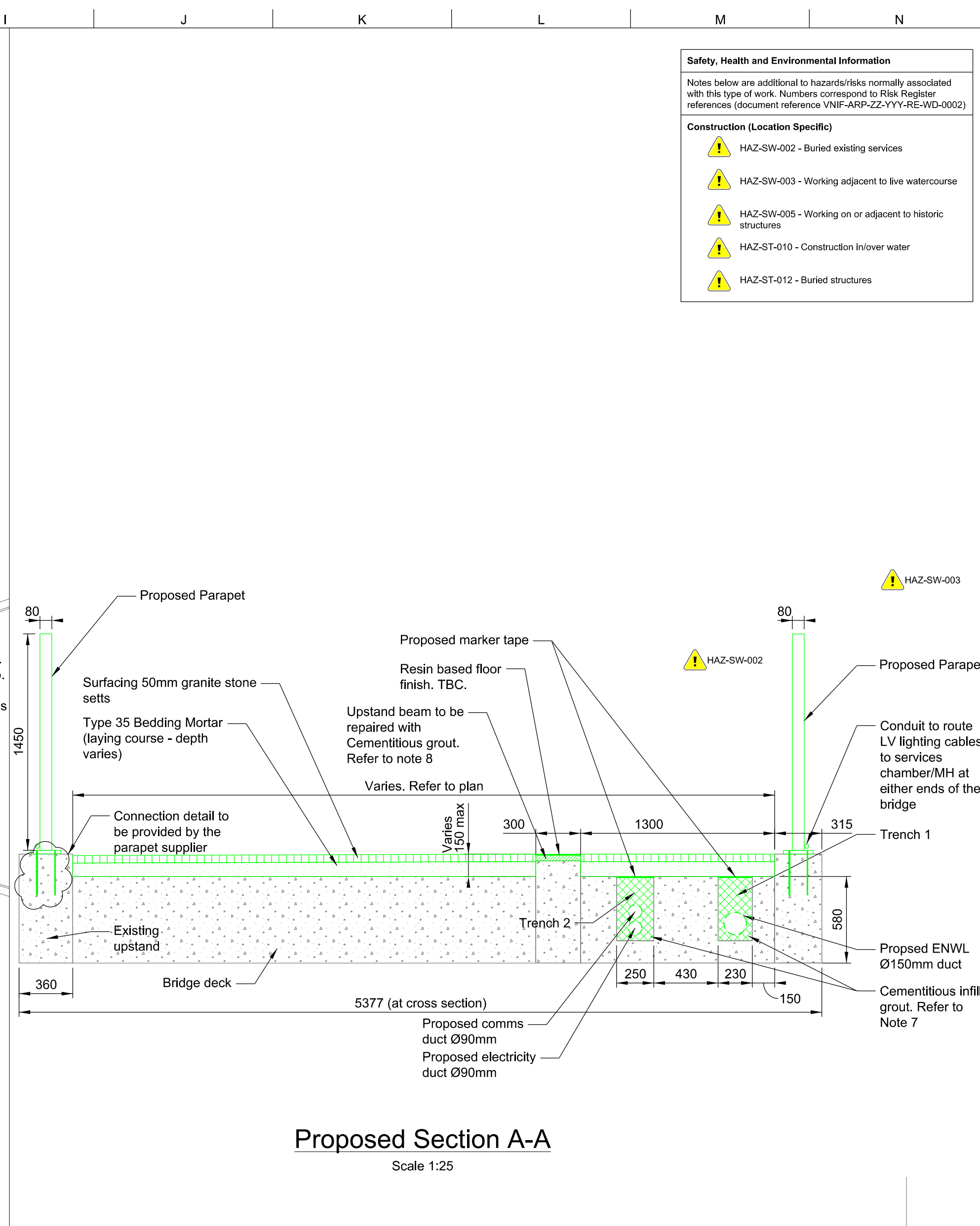
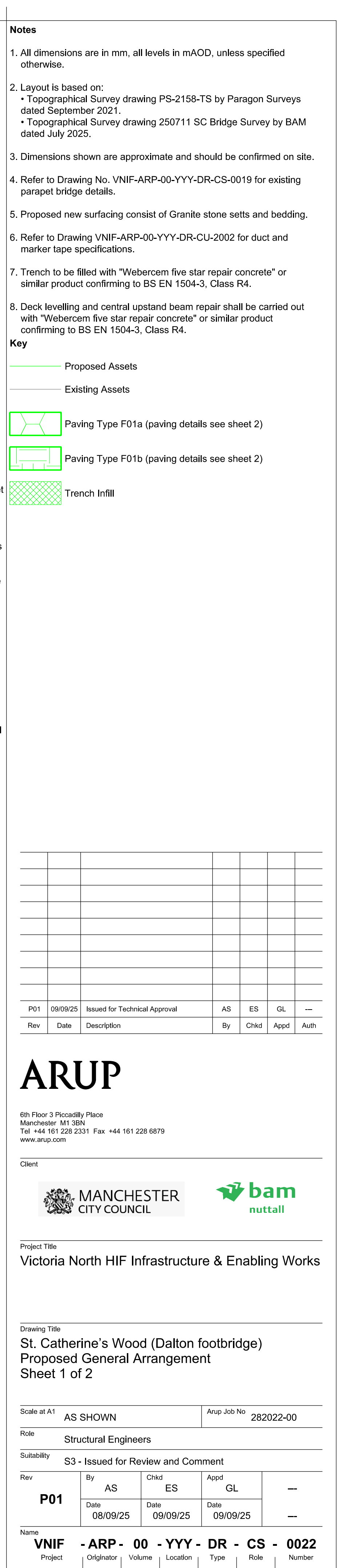
Client



Project Title
Victoria North HIF Infrastructure & Enabling Works

Drawing Title
St. Catherine's Wood Bridge (Dalton footbridge)
Repair Details
Sheet 1 of 2

Scale at A1		N/A		Arup Job No		282022-00	
Role		Structural Engineers					
Suitability		S3 - Issued for Review and Comment					
Rev	By	AS	Chkd	AM	Appd	ES	---
	P01	Date	22/08/25	Date	22/08/25	Date	22/08/25
Name							
VNIF		- ARP- 00 - YYY - DR - CS - 0020					
Project	Originator	Volume	Location	Type	Role	Number	



Appendix D Arup 2022 Baseline Flood Modelling Note

Technical Note

Project title	Victoria North Rivers
Job number	281943-28
File reference	4-05-02
cc	
Prepared by	Louise O'Regan
Date	17 November 2022
Subject	2022 Hydraulic Modelling Update – Rev 5



[arup.com](https://www.arup.com)

1. Introduction

This note describes updates made to the Baseline (Existing Condition) Victoria North hydraulic model in April – June 2022, with additional updates made during November 2022 following a review by the Environment Agency (EA).

The model is a 1D-2D, Flood Modeller Pro – TUFLOW hydraulic model of the River Irk, from Harpurhey to the River Irwell confluence; the Moston Brook, from Failsworth to the River Irk confluence is also represented. The model was created in 2019 through combining of several historic models, as shown in Figure 1:

- 2009 EA Irk model (by JBA) which extended from the A6010 Queens Road Bridge to the Irwell confluence, immediately downstream of Victoria Station culvert (blue);
- 2004 EA Irk model (by Atkins) for approx. 1.5km extent upstream of Queens Road Bridge (red);
- 2007 1D EA model of Moston Brook (purple);
- 2015 EA model of River Irwell.

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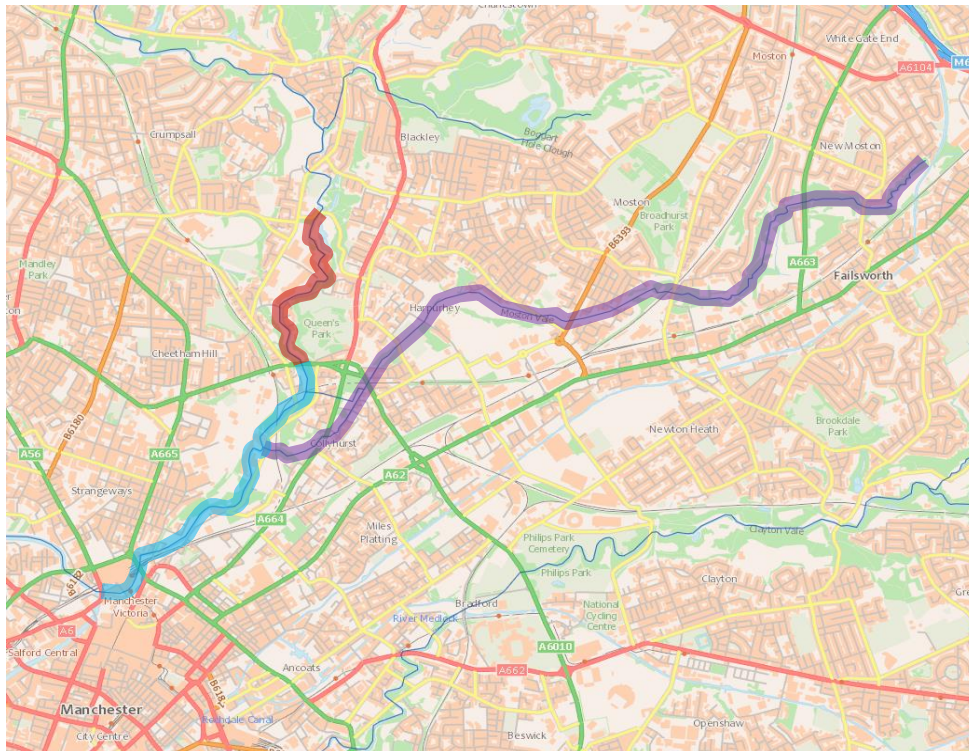


Figure 1: Extents of existing Environment Agency models used

The model was subsequently edited in 2021 to support the Victoria North HIF Infrastructure Works planning application, with the changes made detailed in '*VNIF-ARP-ZZ-RIV-RP-DF-0002_HydrModellingofInfraProposals_Issue4*'. The resulting '*2021 Interim Model*' forms the basis of the work completed here.

The 2021 Interim Model was updated with edits primarily based around the inclusion of additional topographical survey along the River Irk captured as part of the project. Additional survey was considered necessary to improve the performance of the hydraulic model, and improve the model resolution and hydrology calibration to a gauging station situated immediately upstream of Collyhurst Weir. The updates also include actions which remained outstanding from the 2021 Interim Model Environment Agency review; one remaining comment surrounded the incorporation of the 2022 hydrology update, which is described in Section 3.3.

The Baseline model represents the existing condition, as of Quarter 1 2022 (January – March 2022) when additional survey was completed. It is proposed that all future FRAs and 'with scheme' comparisons across the entire Victoria North scheme (including the River and Flood Alleviation Works, phasing checks and any future planning applications that are part of the wider project) will be compared back to this Q1 2022 'Baseline' situation and used as a benchmark for comparisons to assess changes to flood risk.

Following the Environment Agency review in November 2022 and discussions with the project team, the Baseline model which represents the existing condition no longer includes approximately 85m of wall on the right bank (north) of the watercourse immediately upstream of Union Bridge. This wall will be referred to as Union Plaza Wall and is discussed further in Section 3.4.1.

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2. Additional survey data

Additional survey of the watercourse was undertaken by Volker Stevin in February 2022 and a topographic survey of Scotland Weir was completed in April 2022. The key components of these surveys included:-

- Scotland Weir Topo / Bathymetry Survey ref 'SSS-IFA-SW-DR-001-A' by Site Surveying Services Ltd dated 19th April 2022.
- River Irk Topographical including a 3D Laser Scanning Survey ref '2381331_XS_River Irk' Rev B by Central Alliance Survey dated January 2022.
- Collyhurst Weir Topographical including a 3D Laser Scanning Survey ref. '2381331_XS_Collyhurst Weir' Rev B by Central Alliance Survey dated January 2022.

In addition, BAM Nuttall have also conducted a topographical survey of the wider Victoria North Site which has been used to supplement any gaps or verify levels (Ref PS-2158-TS-00.dwg by Paragon Surveys Sept 2021).

2.1 Collyhurst Weir

Additional topographic survey data at Collyhurst Weir was collected to improve confidence in a rating at Collyhurst gauge upstream and downstream of the weir. Whilst the 2019 survey adequately captured a cross section along the crest of the weir, previous survey was not sufficient to allow a good match between the modelled rating and empirical data. Peter Spencer (EA) provided the following recommendations regarding additional survey data, suggesting that for any more modelling a more detailed station-selective survey would be required:

- The channel upstream of the weir should be represented by several surveyed cross sections
- There should also be several cross sections between the end of the simple river section upstream and the expansion to the weir
- A cross section should also represent the exact location of the inlet pipe to the gauging station
- The sections downstream of the weir are required to be detailed, including bridges representation of overtopping of the river channel

11 cross-sections were surveyed along the reach of the River Irk around Collyhurst Weir, extending 50m upstream and 40m downstream of the weir. This captured the widening and narrowing of the channel around the weir and also captured a cross section at the location of the gauge inlet. The location of the surveyed sections compared to the Existing model sections are shown Figure 2.

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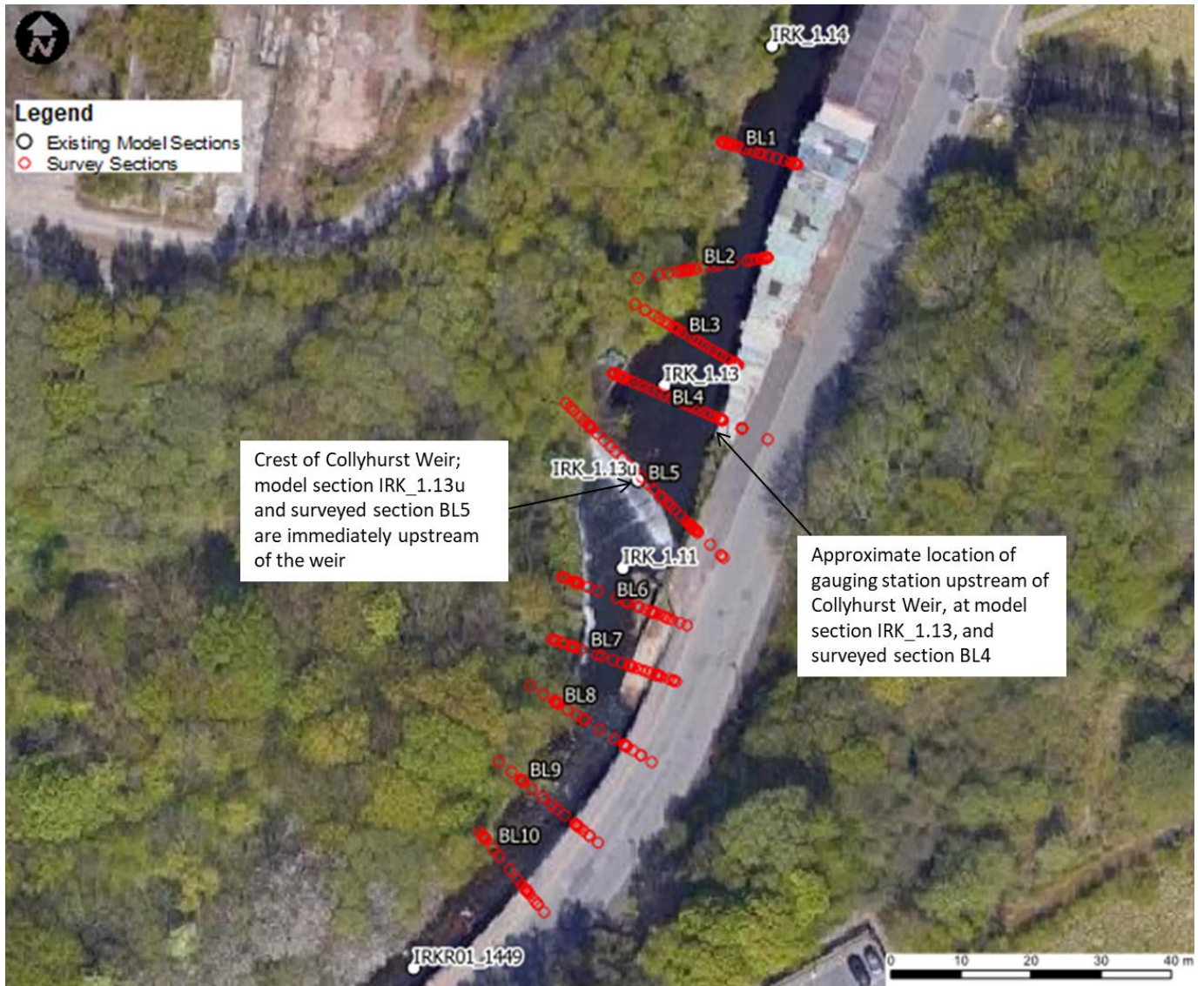


Figure 2: Comparison of the location of Existing model nodes, and surveyed sections at Collyhurst Weir.

2.2 Union Bridge

22 cross-sections were surveyed in the reach around Union Bridge, extending approximately 160m upstream and 130m downstream of the bridge; a comparison between the surveyed sections and Existing model sections is shown in Figure 3.

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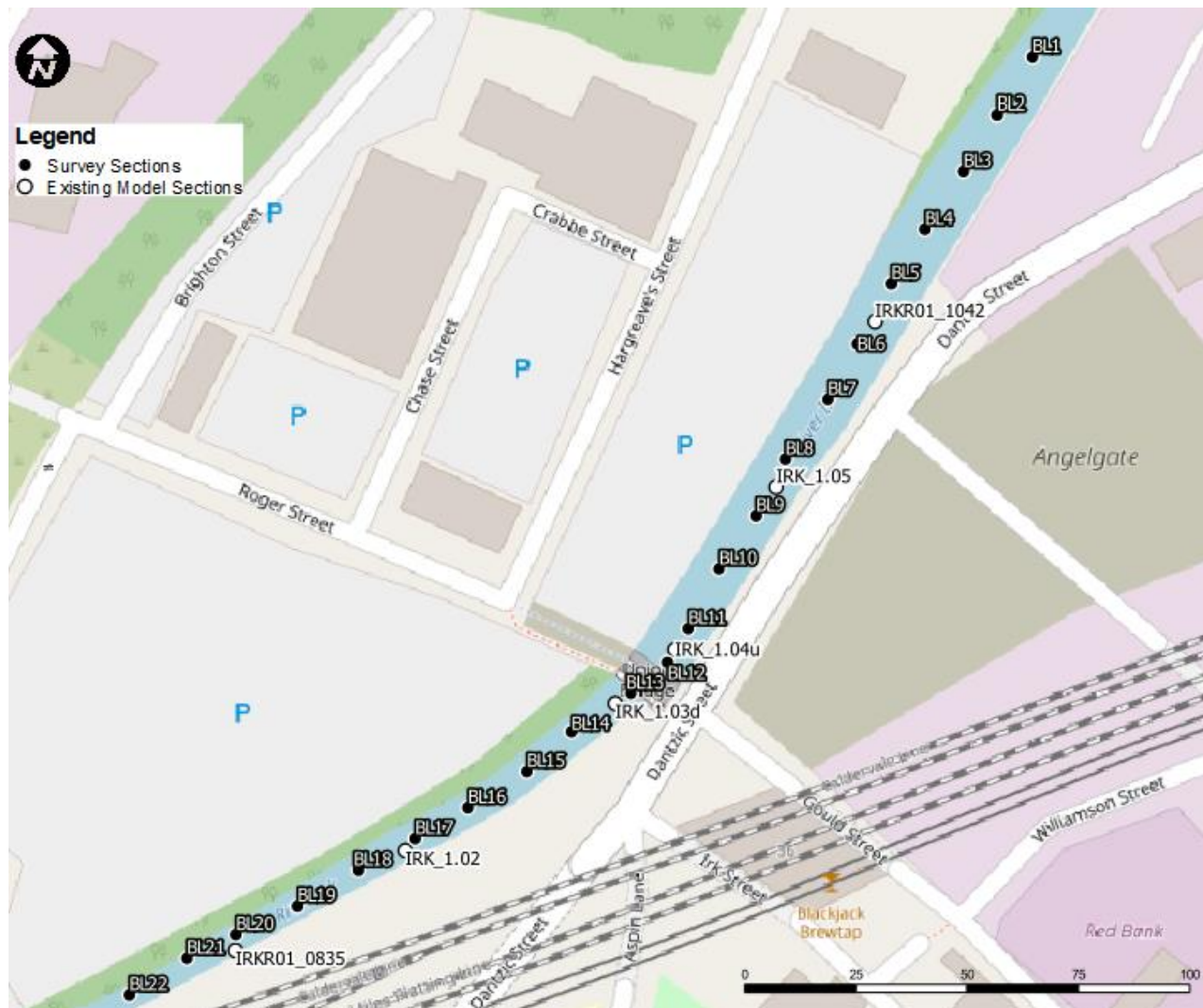


Figure 3: Comparison of the location of Existing model sections and survey sections, along the River Irk around Union Bridge

2.3 Aspin Lane culvert

19 cross-sections around, and through, the Aspin Lane culvert were surveyed, extending 20m upstream, 130m through, and approximately 85m downstream of the culvert (Figure 4).

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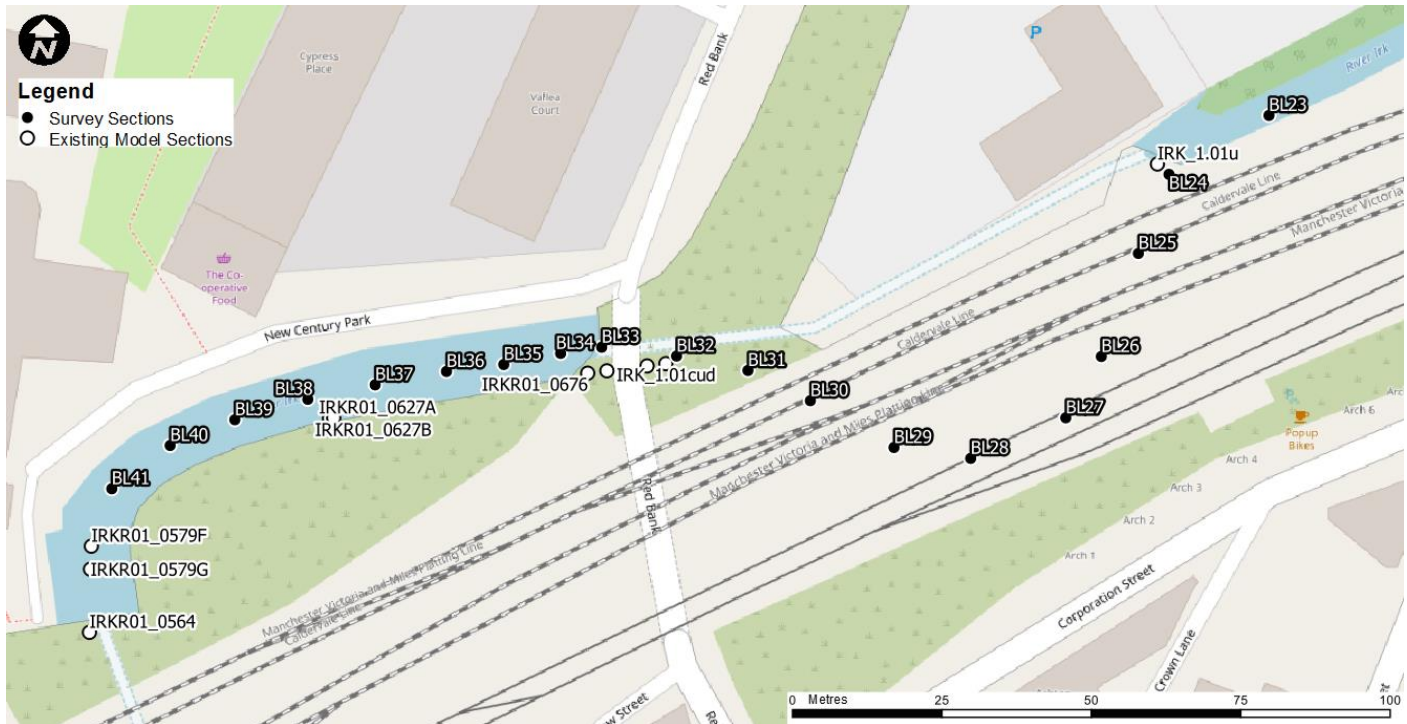


Figure 4: Comparison of the location of Existing model sections and survey sections, along the River Irk around the Aspin Lane culvert

2.4 Survey review

The received surveyed cross-sections were cleaned to remove points representing non-solid structures, such as fences, which are considered to have no effect on out of bank flows. Hard bed levels from the survey have been used as it is assumed that a flood event would remove smaller channel sediments represented by the soft bed levels; there was also more complete data around hard bed levels compared to soft bed levels.

A comparison of Existing model cross-sections and surveyed cross-sections around Collyhurst Weir has been undertaken, shown in Figure 5 – 9 (see Figure 2 for the locations of the cross-sections compared). Broadly, the comparisons show that the cross-section shape is the same between the Existing model (shown in black) and the newly surveyed sections (shown in red).

[Note, for visual comparison purposes, the x coordinates of new survey cross sections have been shifted along the x-axis in the figures below].

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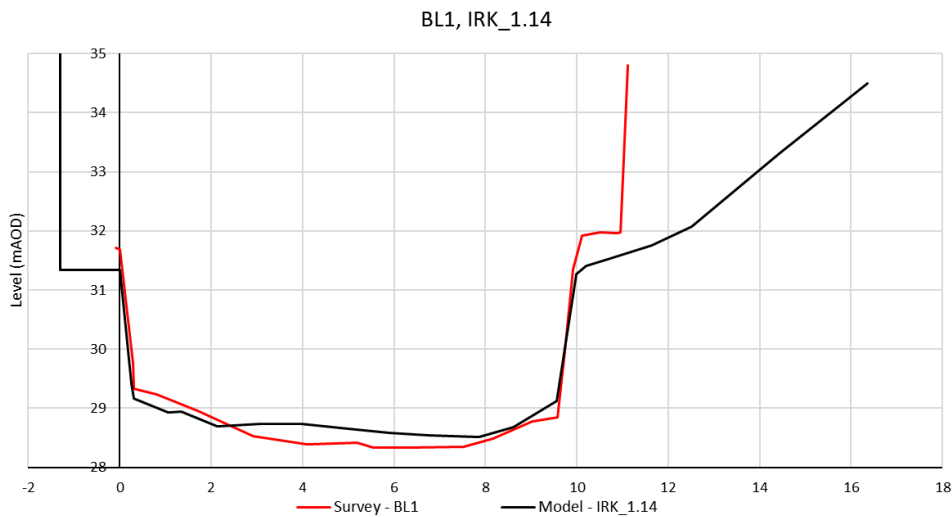


Figure 5: Comparison of the existing model section, IRK_1.14, and the surveyed cross-section, BL1

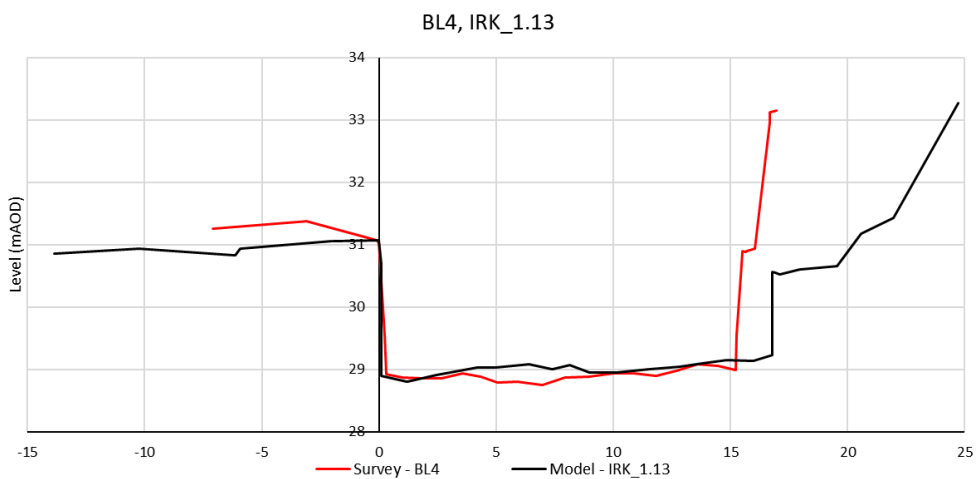


Figure 6: Comparison of the Existing model section, IRK_1.13, and the surveyed cross-section BL4

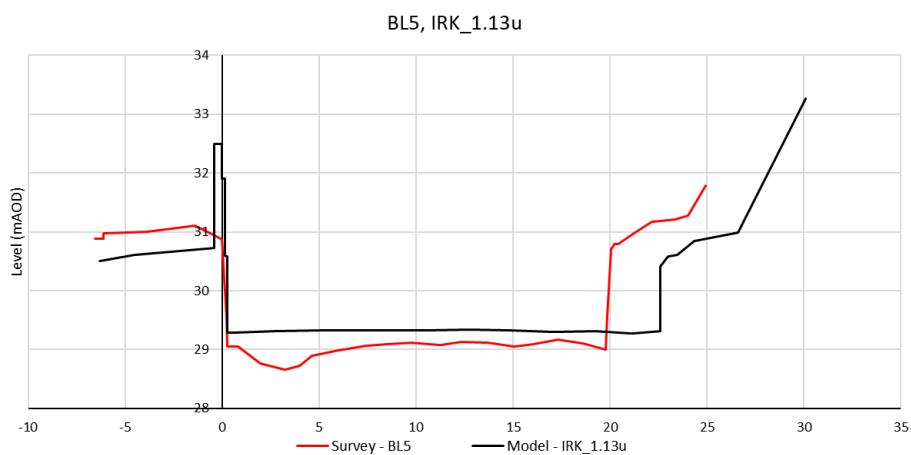


Figure 7: Comparison of the Existing model section, IRK_1.13u, and the surveyed section BL5

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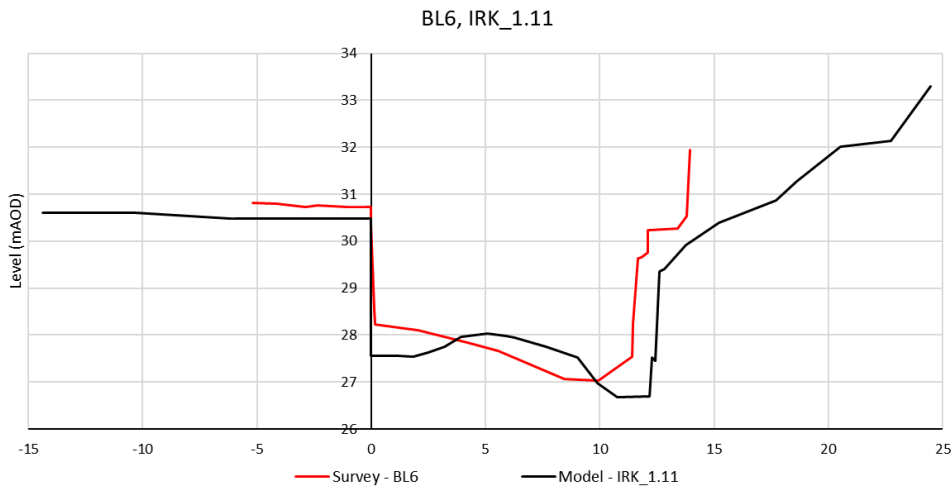


Figure 8: Comparison of the Existing model section, IRK_1.11, and the surveyed cross-section BL6

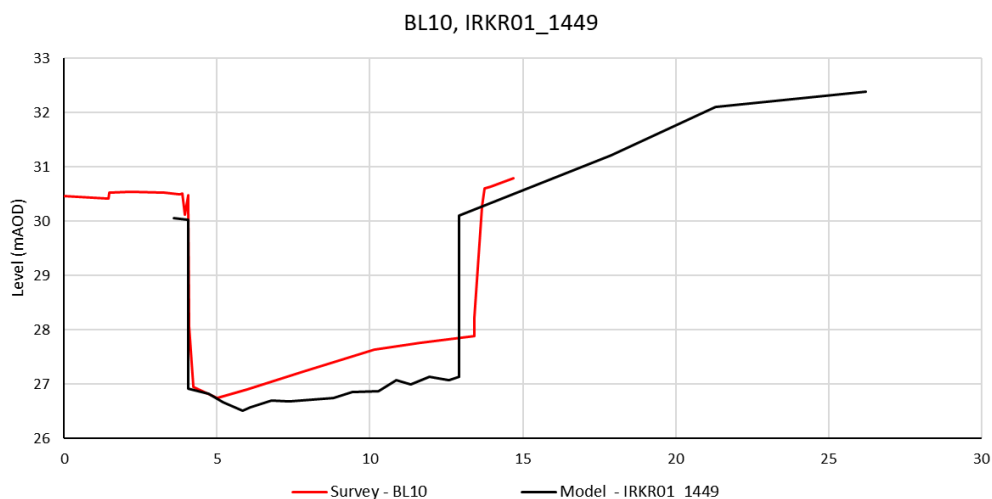


Figure 9: Comparison of the Existing model section, IRKR01_1449, and the surveyed cross-section BL10

Similarly, a comparison between the Existing model sections and surveyed cross-sections around Union Bridge was undertaken, shown in Figure 10 – 21 (Figure 3 shows the location of the sections compared). Broadly, the comparison shows that the cross-section shape is the same between the Existing model and surveyed sections.

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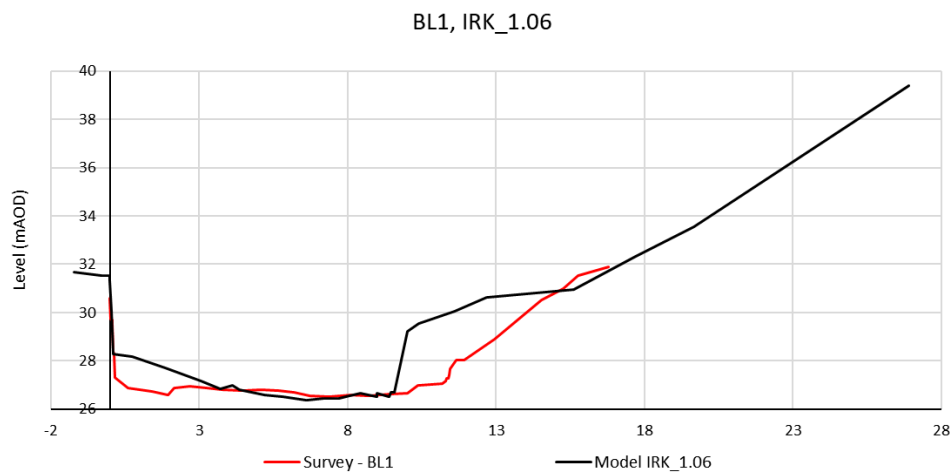


Figure 10: Comparison of the Existing model section, IRK_1.06, and the surveyed section BL1

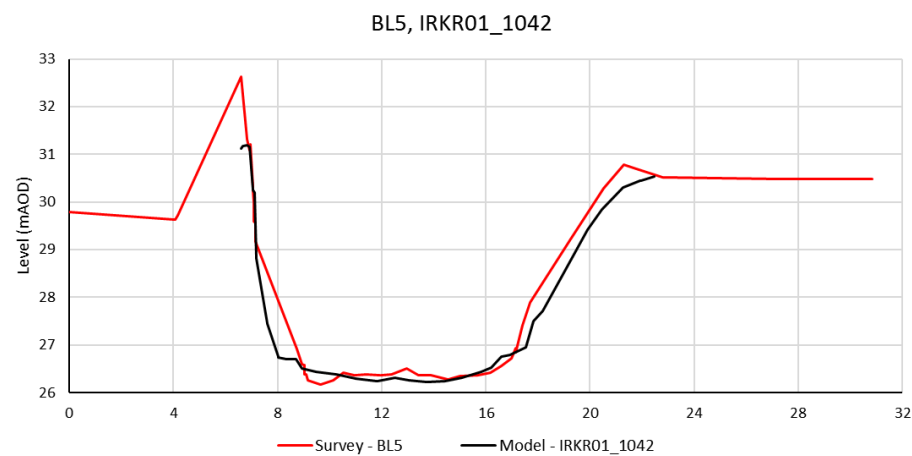


Figure 11: Comparison of the Existing model section, IRKR01_1042, and the surveyed section BL5

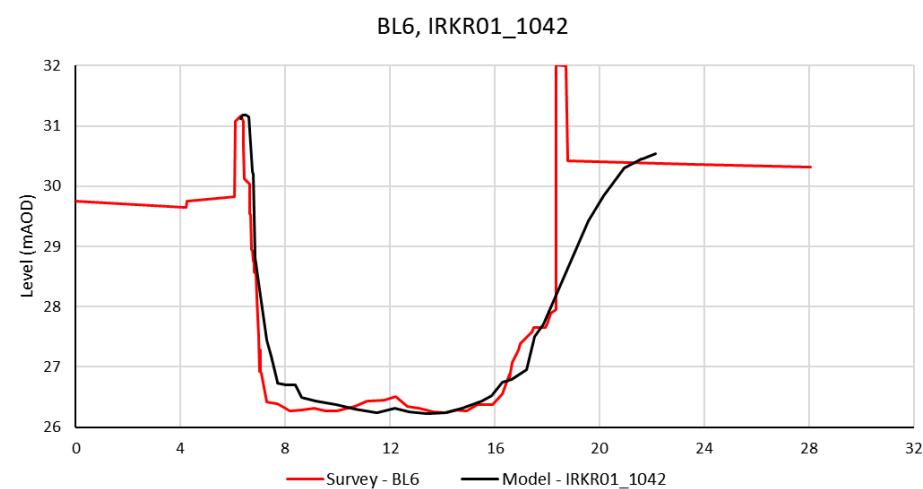


Figure 12: Comparison of the Existing model section, IRKR01_1042, and the surveyed section BL6

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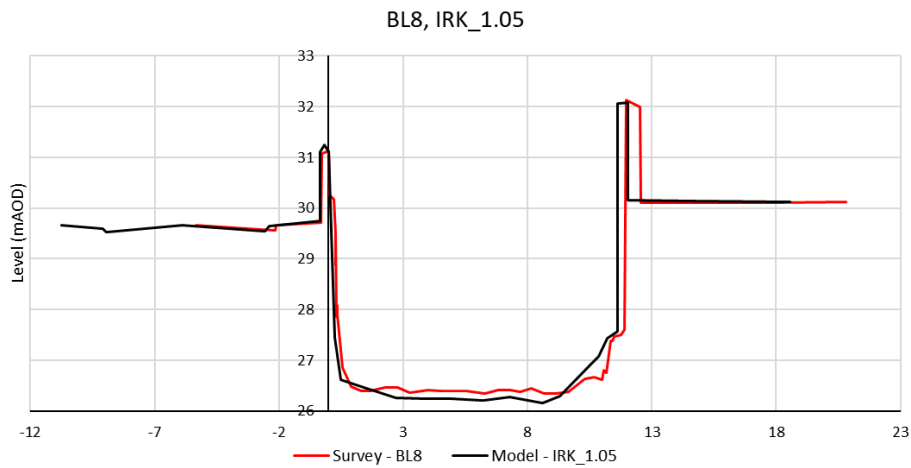


Figure 13: Comparison of the Existing model section, IRK_1.05, and the surveyed section BL8

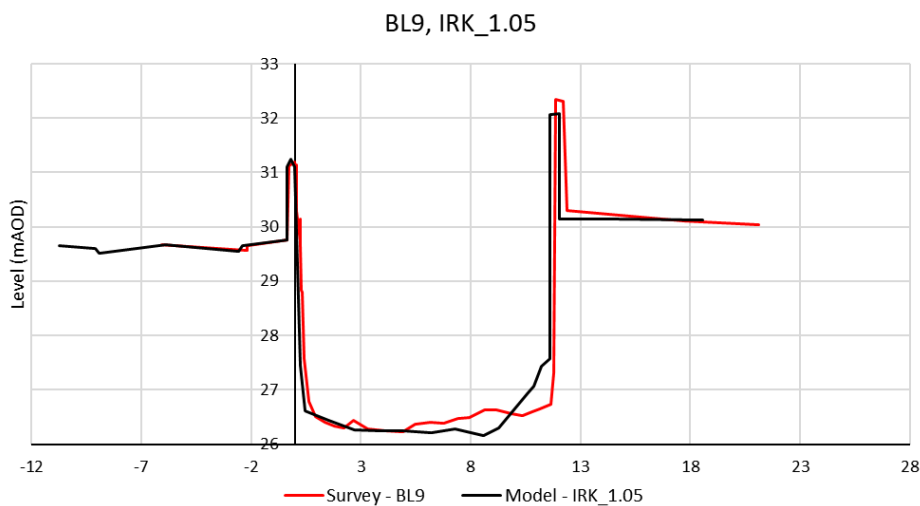


Figure 14: Comparison of the Existing model section, IRK_1.05, and the surveyed section BL9

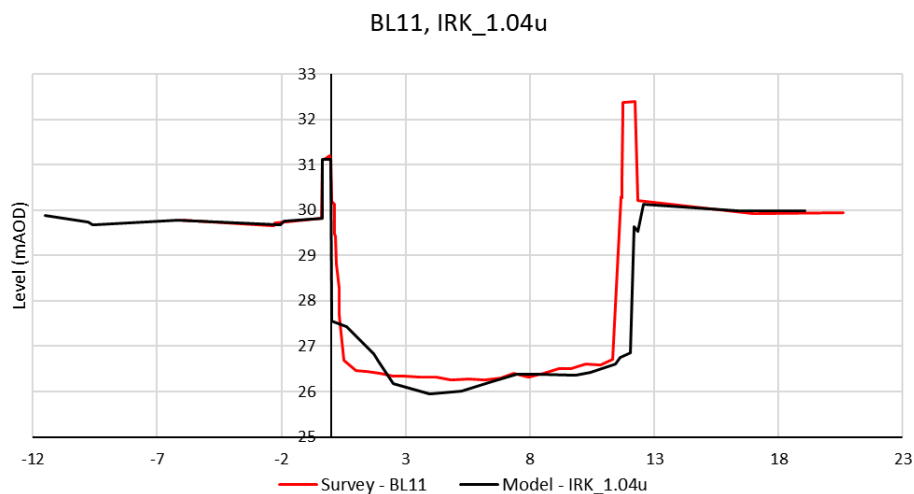


Figure 15: Comparison of the Existing model section, IRK_1.04, and the surveyed section BL11

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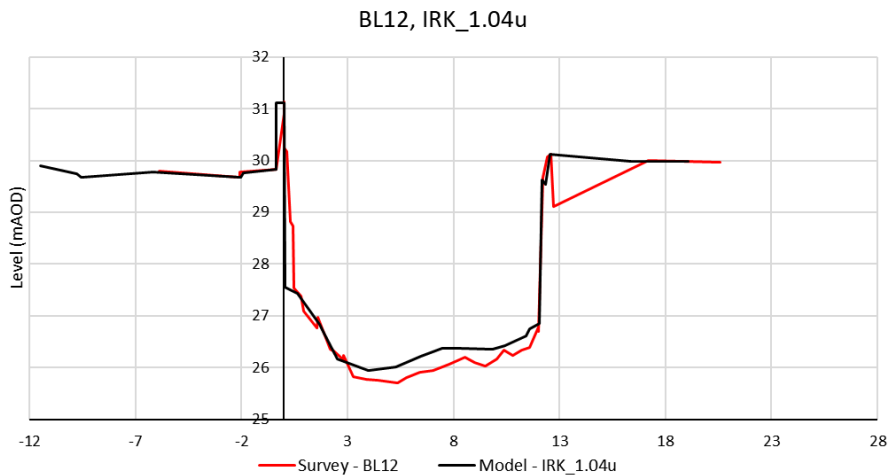


Figure 16: Comparison of the Existing model section, IRK_1.04u, and the surveyed section BL12

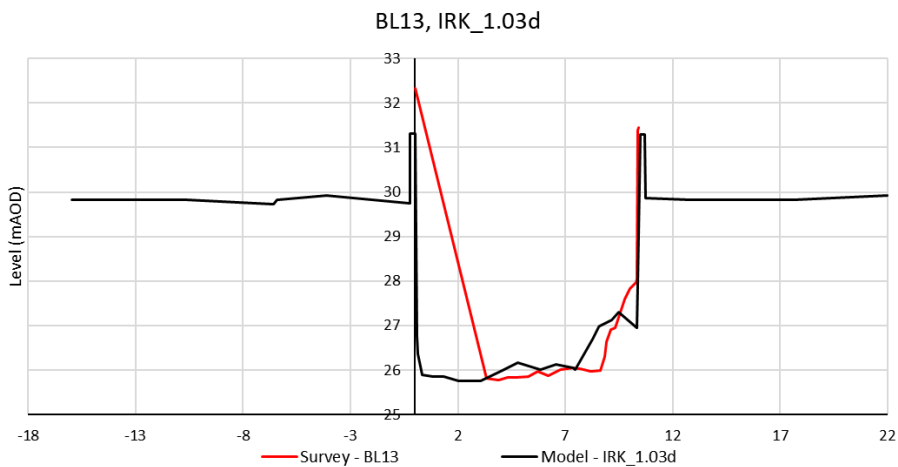


Figure 17: Comparison of the Existing model section, IRK_1.03d and the surveyed section BL13

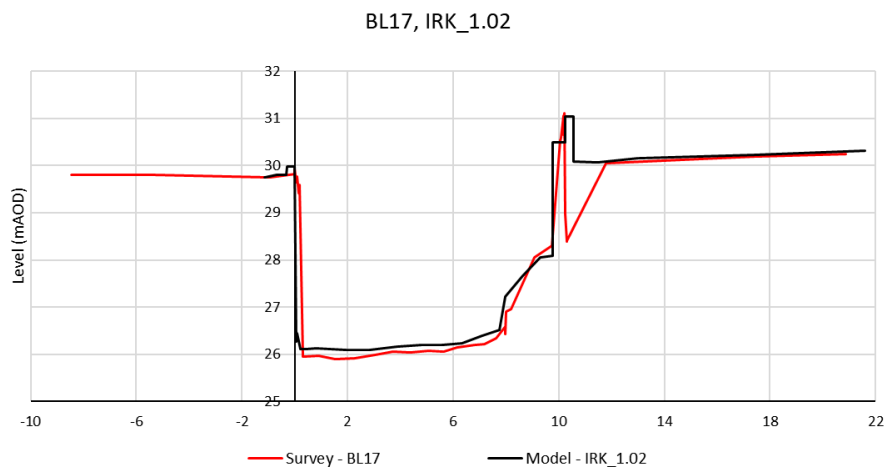


Figure 18: Comparison of the Existing model section, IRK_1.02, and the surveyed section BL17

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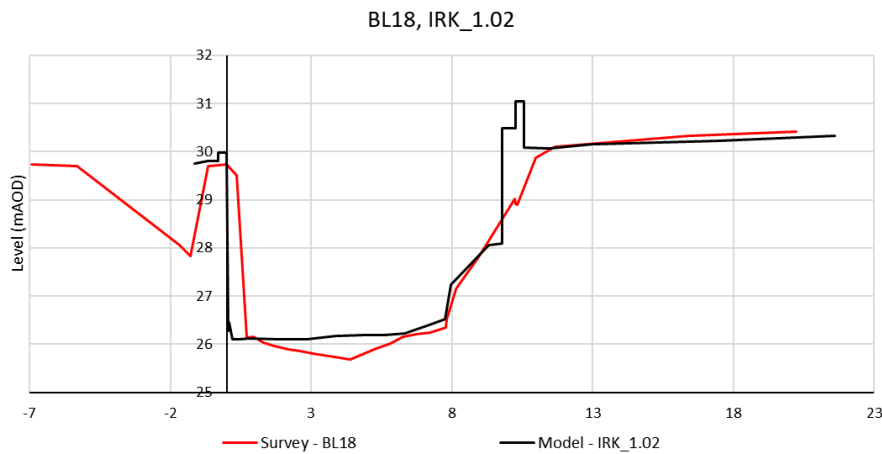


Figure 19: Comparison of the Existing model section, IRK_1.02, and the surveyed section BL18

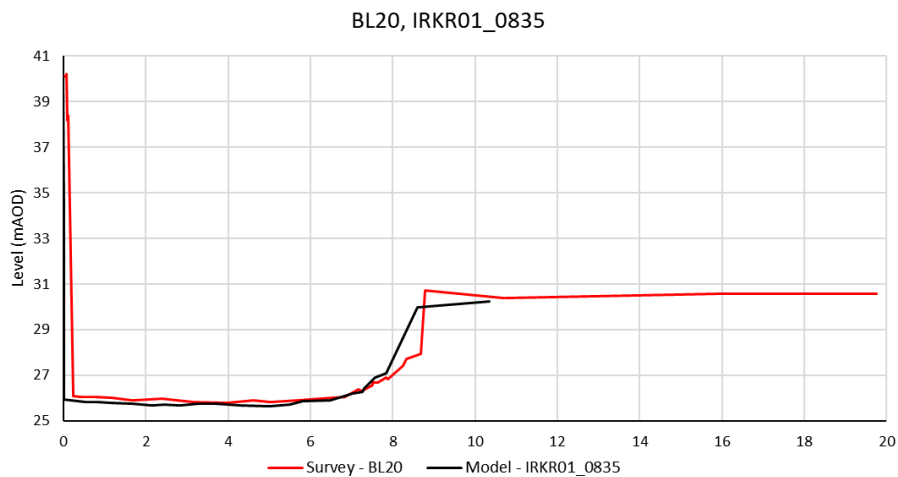


Figure 20: Comparison of the Existing model section, IRKR01_0835 and the surveyed section BL20

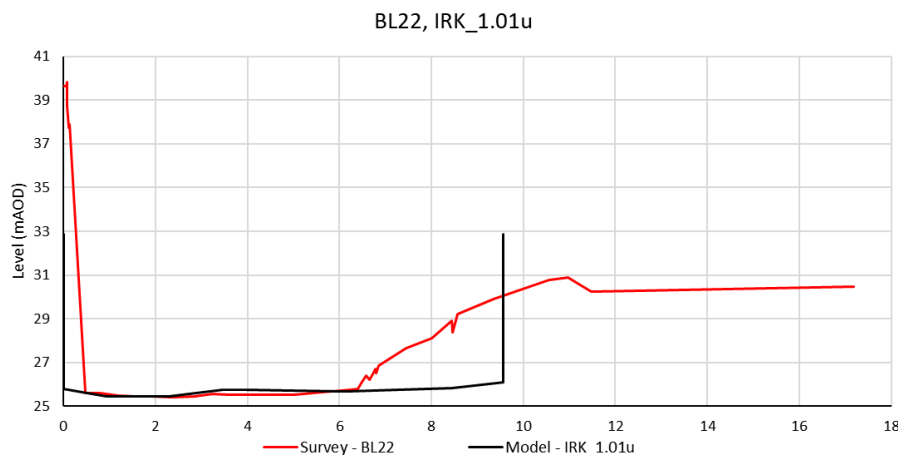


Figure 21: Comparison of the Existing model section, IRK_1.01u and the surveyed section BL22

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Similarly, a comparison between the Existing model sections and surveyed cross-sections around Aspin Lane culvert and Aspin Lane Bridge was undertaken, shown in Figure 22– 26 (Figure 4 shows the location of the sections compared). Broadly, the comparison shows that the cross-section shape is the same between the Existing model and surveyed sections.

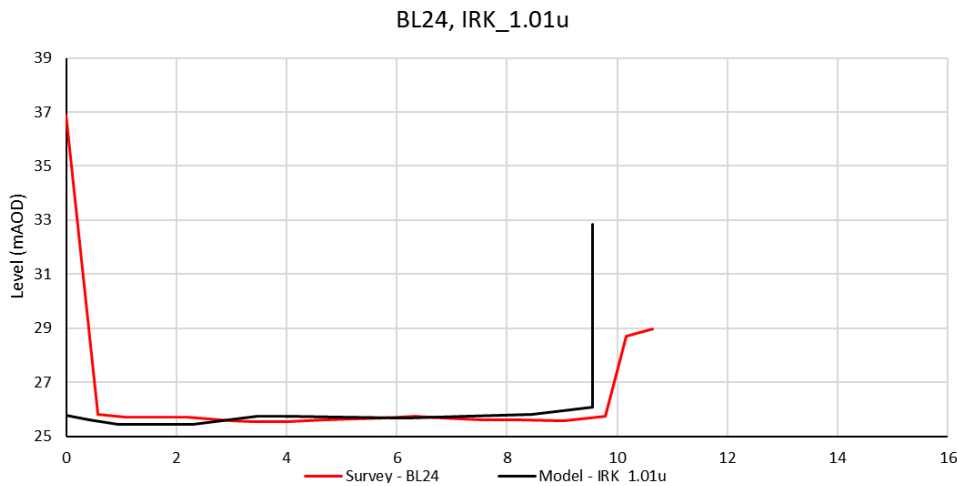


Figure 22: Comparison of the Existing model section IRK_1.01u and surveyed section BL24

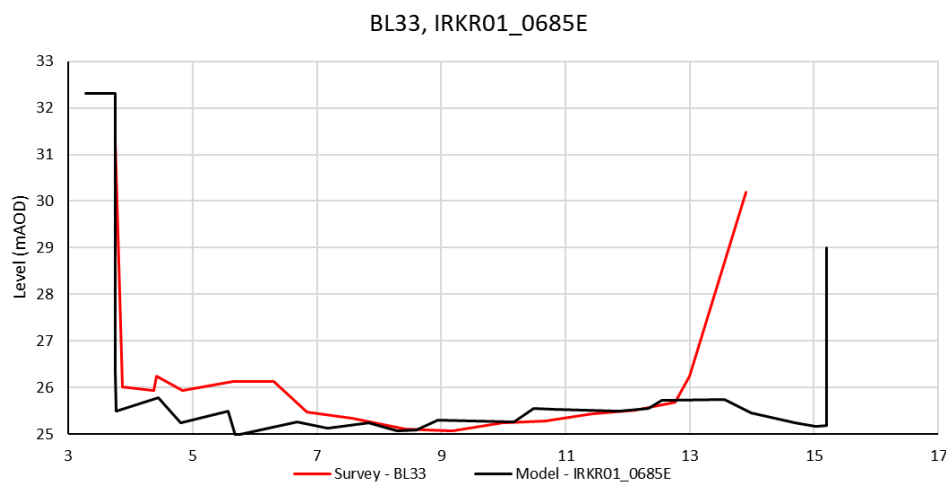


Figure 23: Comparison of the Existing model section IRKR01_0685E and surveyed section BL33

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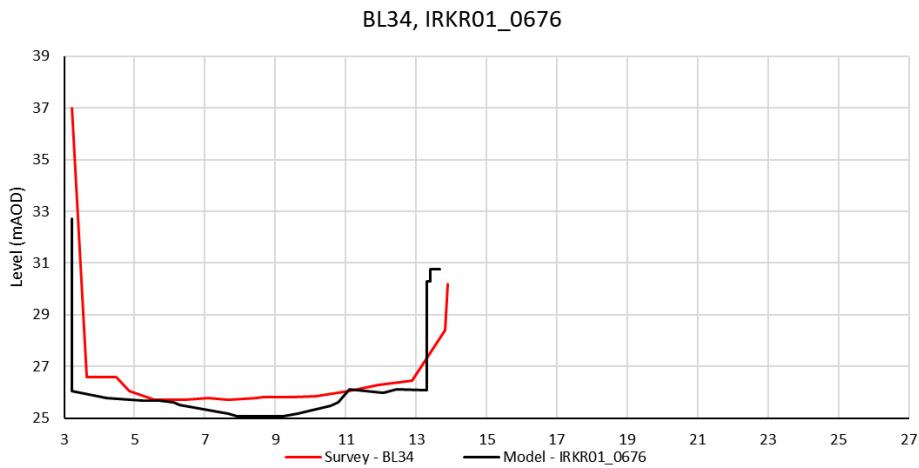


Figure 24: Comparison of the Existing model section IRKR01_0676 and surveyed section BL34

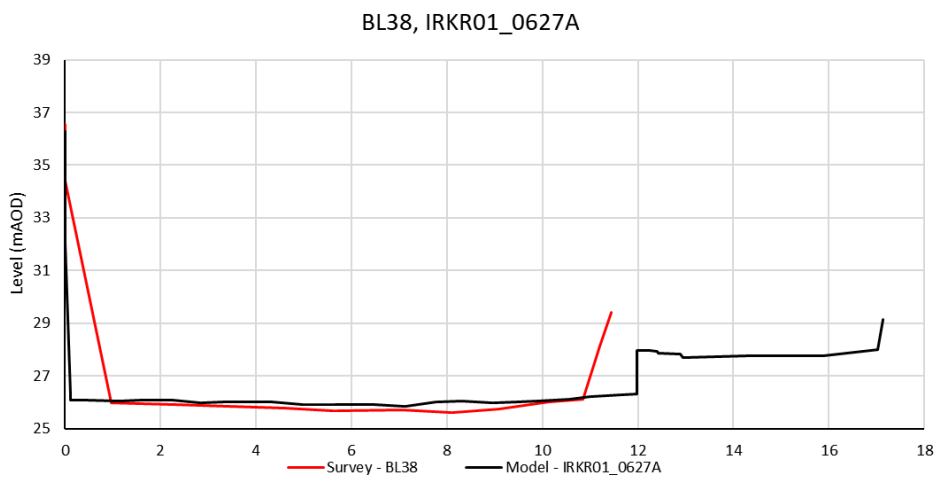


Figure 25: Comparison of the Existing model section IRKR01_0627A and surveyed section BL38

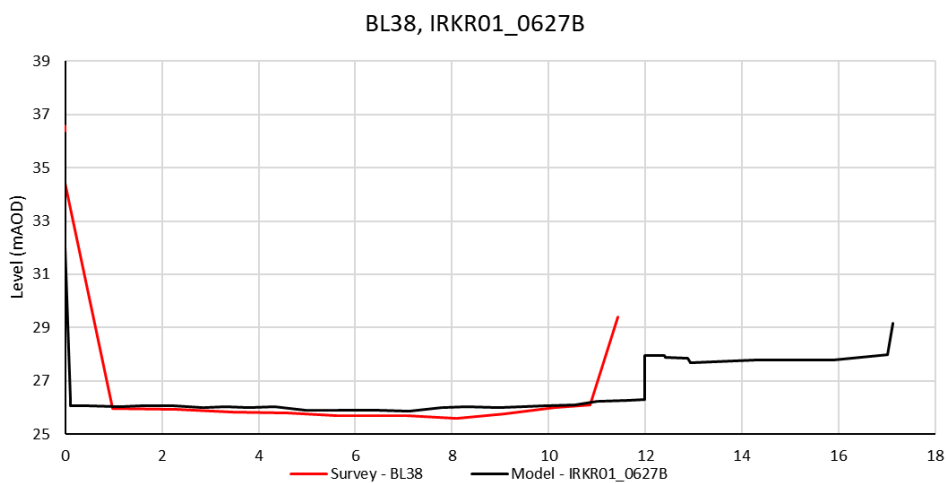


Figure 26: Comparison of the Existing model section IRKR01_0627B and surveyed section BL38

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3. Model update methodology

The survey was used to replace the Existing model cross-sections, rather than supplementing them, as the sections were surveyed with a spacing of approximately 15m (although this spacing is variable). Supplementing existing model sections would have created short channel reaches, which may have affected model stability. While the naming of the newly surveyed cross-sections did not reference chainage, this was updated by measuring distances in GIS software, between the received surveyed sections and the existing model cross-sections, which do reference chainage. In some locations, the addition of interpolate units was necessary to ensure that cross-section spacing is not considered to be erratic. Both the 1D and 2D domains of the model were updated to account for the addition of the survey.

3.1 Survey - 1D model updates

3.1.1 Collyhurst Weir

Collyhurst Weir was previously modelled using a Flood Modeller “General Weir” unit; while it was initially considered that a “Broad-crested Weir” unit would be perhaps more representative of the weir profile, the “General Weir” unit was retained as it provided more accurate calibration results (see Section 3.3 for a description of the hydrology updates made). The geometry of the weir unit was updated based on the received survey, while the “*Discharge Coefficient*”, “*Modular Limit*” and “*Exponent*” values were optimised to ensure the model accurately represents the behaviour of Collyhurst Weir, based on observed gauge station data.

Surveyed sections *BL2*, 49m upstream of Collyhurst Weir, was considered to be skewed (Figure 27); as such, the skew angle was measured and used to adjust the cross-section width. This led to a reduction in the width of the cross-section, from 18.673m measured from survey, to 17.059m when adjusted for cross-section skew. Section *IRKR01_1509u*, immediately upstream of the weir, was taken from the 2021 Interim Model, as this was shown to provide the best match to observed gauge data (Section 3.3.1).

While these changes were initially made to improve the model performance during calibration, they were also applied to the Baseline model to ensure model performance was optimised. See Section 3.3.1 for more information on the calibration.

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Figure 27: Surveyed cross-section data plotted, clearly showing the skew of sections BL2 and BL5

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3.1.2 Union Bridge

Survey cross-sections *BL12* and *BL13* represent the upstream and downstream sections of Union Bridge respectively, as shown in Figure 3. The survey of section *BL12* is complete, however the survey of section *BL13* is not complete, due to access and associated safety issues at the time of survey. As a result of this, section *BL12* was used to represent both the upstream bridge section and bridge geometry, in the model unit *IRKR01_0941u*. Where survey of section *BL13* is available, this was used to represent the downstream face of the bridge in section *IRKR01_0941d*; section geometry from *BL12* was used where data from section *BL13* is not available. Figure 28 illustrates the upstream and downstream section geometry, as defined in the model.

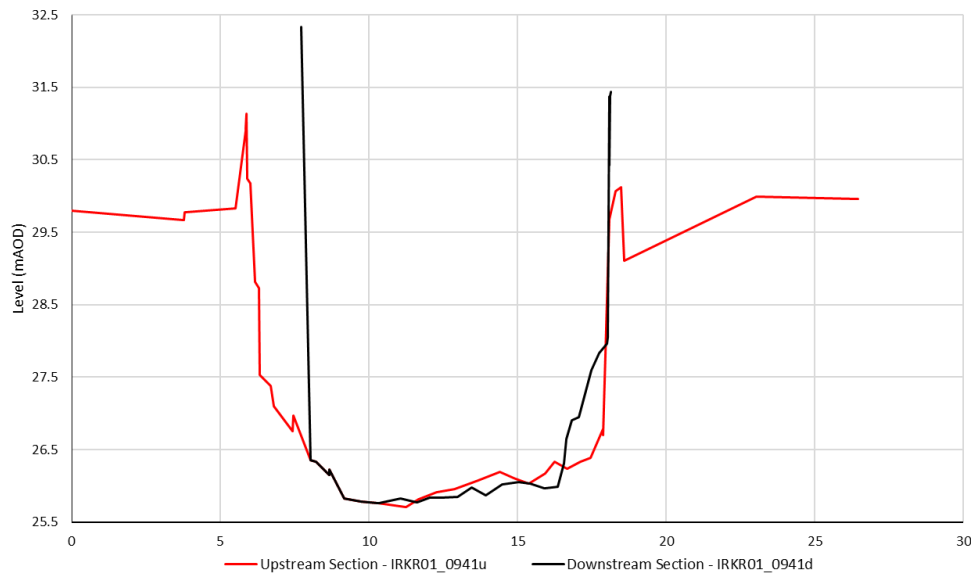


Figure 28: Comparison of upstream and downstream section geometry at Union Bridge

3.1.3 Aspin Lane culvert and Aspin Lane (Scotland) Bridge

Previously, the model represented the Aspin Lane culvert as a sprung-arch type culvert, 89m in length; the 2022 survey shows that there are multiple shape changes over 130m. The culvert was updated using asymmetrical conduit units, enabling the model to represent the shape and bed level changes shown in the surveyed cross-sections. Culvert outlet loss units were applied where the cross-sections illustrated a change in shape, between survey sections *BL25* and *BL26*, *BL26* and *BL27*, *BL28* and *BL29*, *BL29* and *BL30*, and *BL31* and *BL32*. As such, to enable the model to run while using culvert outlet loss units, copies of sections are used to represent the upstream and downstream faces of the culvert where these shape changes occur. While the survey indicated the presence of beams in the culvert cross-sections, these were represented by an increased roughness of the culvert soffit, rather than being explicitly represented in section geometry. A value of 0.03 was used for the soffit roughness where beams were present, increased from a value of 0.015 where beams were not present. These values were based on the values for brickwork closed conduits in the 1959 Chow roughness tables.

Similarly, Aspin Lane Bridge was updated, and represented using an irregular conduit unit, rather than an arch bridge unit, as a result of the 12m bridge length, and the change in soffit level through the bridge shown in the surveyed cross-sections. Compared to the 2021 Interim Baseline Model, the bridge is a more restrictive structure. The 2022 survey shows the soffit level of the bridge to be 28.28 – 28.37mAOD, with a width of 8.27 – 9.32m, while the 2021 model shows the soffit level to be 28.67mAOD, with a width of 9.92m.

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3.1.4 Roughness values

To represent roughness in the model cross-sections, Manning's n values were assigned to the additional surveyed cross-sections in the model, based on the 1959 Chow roughness tables. The values were compared to the Existing model sections upstream and downstream of additional sections. In the absence of survey photos, values were checked for suitability against online imagery, and cross-section descriptions. Panel markers were also added at changes of Manning's n values (across channel width).

3.1.5 Cross-section naming convention

The model cross-sections added from the 2022 survey were named as such: *IRKR01_XXXX*, where *XXXX* varies for each cross-section, and represents cross-section chainage. The chainage value used in the naming convention was measured for each additional cross-section, based on existing model cross-sections. Table 1 details the model node name for each of the surveyed cross-sections.

Table 1: The model cross-section naming convention, listing the received survey cross-section names, with the names given to the node when added to the model. Not all nodes added to the Aspin Lane sections are detailed, as some are related to the addition of culvert outlet loss units, rather than corresponding to a specific surveyed section

Collyhurst Weir sections		Union Bridge Sections		Aspin Lane Sections	
Survey name	Model name	Survey name	Model name	Survey name	Model name
BL1	IRKR01_1576	BL1	IRKR01_1111	BL23	IRKR01_00794
BL2	IRKR01_1558	BL2	IRKR01_1096	BL24	IRKR01_00775u
BL3	IRKR01_1548	BL3	IRKR01_1081	BL25	IRKR01_00761
BL4	IRKR01_1539	BL4	IRKR01_1066	BL26	IRKR01_00742
BL5	IRKR01_1509u	BL5	IRKR01_1051	BL27	IRKR01_00731
BL6	IRKR01_1509d	BL6	IRKR01_1036	BL28	IRKR01_00713
BL7	IRKR01_1501	BL7	IRKR01_1022	BL29	IRKR01_00700
BL8	IRKR01_1492	BL8	IRKR01_1005	BL30	IRKR01_00684
BL9	IRKR01_1480	BL9	IRKR01_0991	BL31	IRKR01_00673
BL10	IRKR01_1470	BL10	IRKR01_0976	BL32	IRKR01_00660
		BL11	IRKR01_0961	BL33	IRKR01_00648d
		BL12	IRKR01_0941u	BL34	IRKR01_00641
		BL13	IRKR01_0941d	BL35	IRKR01_00631
		BL14	IRKR01_0925	BL36	IRKR01_00621
		BL15	IRKR01_0912	BL37	IRKR01_00609
		BL16	IRKR01_0897	BL38	IRKR01_00598
		BL17	IRKR01_0883	BL39	IRKR01_00585
		BL18	IRKR01_0868	BL40	IRKR01_00573

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		BL19	IRKR01_0852	BL41	IRKR01_00561
		BL20	IRKR01_0837		
		BL21	IRKR01_0825		
		BL22	IRKR01_0809		

3.2 Survey - 2D model updates

In addition to the 1D-domain model updates, the 2D-domain was also updated to include the 2022 survey. In order to connect the additional cross-sections, added to the 1D model based on survey, nodes were added to the 2D model, in addition to CN and HX lines to connect each node to the 1D domain. The inactive code layer, representing the River Irk channel, and ensuring that the channel is represented in the 1D domain only, was edited and snapped to the updated HX lines. This ensures that flow is not double counted. The 1D channel width was compared to the 2D channel width, again to ensure that flow is not double counted; edits were made to the position of HX and CN lines, in addition to deactivation markers on 1D cross-sections. To ensure that the 2D spilling level is accurate in the model, bank levels were defined using levels taken from the 1D model cross-sections.

Similarly, the positioning of the 1D-2D channel location was altered downstream of the Aspin Lane culvert, to better match the position of the channel in the LiDAR used in the model. The associated nodes layer, HX and CN lines, and bank lines were also adjusted to account for the change in the channel position.

The LiDAR Digital Terrain Model (DTM) used in the model appeared to show a channel through the Aspin Lane culverts due to incorrect filtering; to ensure this does not impact model results, *2d_zsh_AspinLane_TopoPatch_001_R.shp* was used to smooth this inaccuracy. The LiDAR also appeared to have incorrectly removed the viaduct through the site, between Bromley Street and Manchester Victoria Station, resulting in incorrect overland flow paths being represented by the model. *2d_zsh_AspinLaneViaduct_001_R.shp* and *2d_zsh_AspinLaneViaduct_001_P.shp* were added to the model to ensure that the viaduct is correctly included in the model. The A665 junction with Cheetham Hill Road was also represented in this layer, to account for its removal in the LiDAR DTM. Similarly, the disused railway sidings at Red Bank, appeared to be removed from the LiDAR, and so was added to the model using *2d_zsh_DisusedViaduct_001_R.shp*, and *2d_zsh_DisusedViaduct_001_P.shp*. This included an opening to represent Faber Street. The LiDAR Digital Surface Model, which has not been filtered for surface features, was used to define these features.

Definition of the deck geometry and levels of Union Bridge, and parapet wall on the downstream face of the structure, in the 2D-domain have been updated using topographic survey from BAM.

3.3 Hydrology update

Updates to the hydrology inflows used in the model were also updated as described in technical note *VNR-ARP-00-YYY-RP-CH-0001_Flood Estimation Report*.

There has been a negligible change in flow estimates as a result of the updates made to the hydrology inflows, however they have been brought in line with latest flood estimation techniques. The Flood Zone 2 and 3 extents occupy more of the site than historically, shown in Figure 29 and Figure 30, which is dominantly driven by the model updates.

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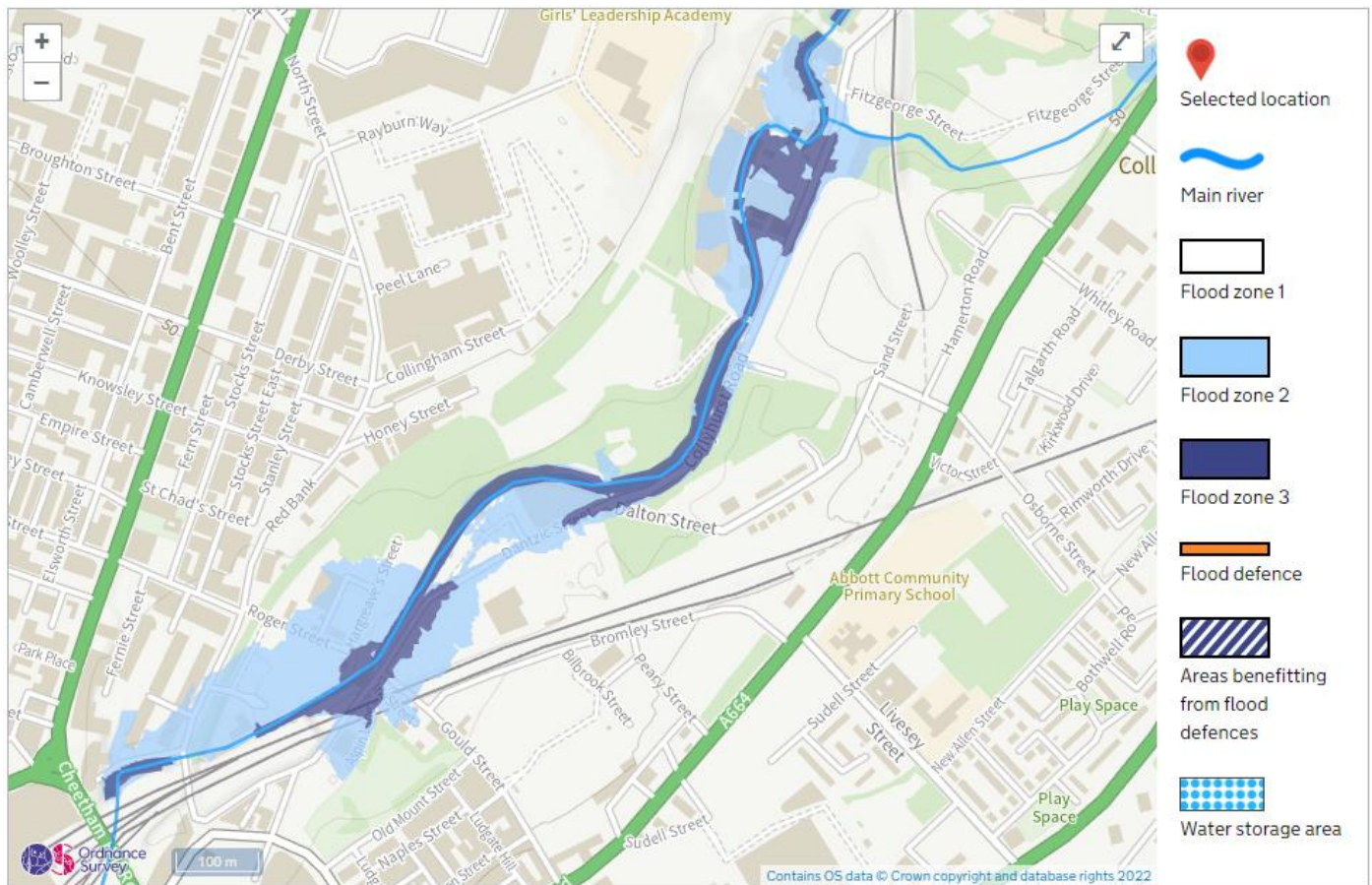


Figure 29: Current flood zones, taken from the Environment Agency Flood Map for Planning. Accessed here: <https://flood-map-for-planning.service.gov.uk>, on 20/07/2022.

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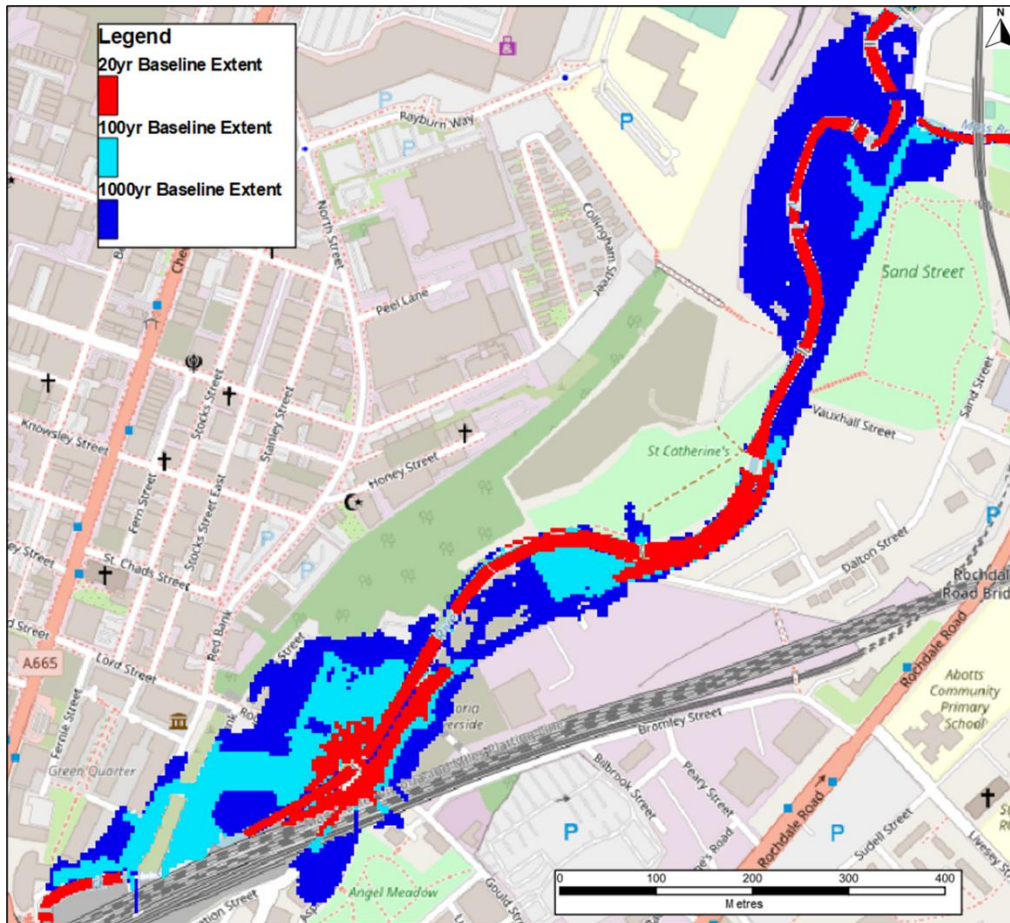


Figure 30: Updated flood extents, taken from the 2022 Baseline model and run using the 2022 hydrology.

3.3.1 Calibration at Collyhurst weir

Recent spot gauging data collected at Collyhurst Weir in winter 2021/22 has allowed the rating at Collyhurst Weir gauge to be revisited. Survey data collected (detailed in Section 2.1) was used to update the hydraulic model and a sensitivity testing exercise was carried out to test how elements such as cross section skew, weir representation (such as the Discharge Coefficient, Modular Limit and Exponent) impacted on the rating. The sensitivity testing exercise also sought to use the survey data in the model to fit to the empirical gauge data.

To aid analysis of the rating, the full hydraulic model was truncated to between nodes IRK_1.15d, approximately 120m upstream of Collyhurst Weir, and IRKR01_1188A, 320m downstream of the structure, and was run in 1D domain only. This allowed the lower part of the rating curve to be assessed, but was not suitable for the higher limb of the rating curve due to not capturing the 2D flow routes or a minor backwater effect. The truncated model allowed a range of runs for multiple model configurations to be undertaken without the long simulation times associated with the full 1D-2D hydrodynamic model.

The truncated model was initially based on the full Baseline model, which included the additional survey (received April 2022) in the reach around Collyhurst Weir. As detailed above, the rating models were initially run in the 1D domain only, with Table 2 detailing the key changes made to the different iterations of the models.

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Table 2: Details of the models used to support the hydrology rating exercise.

Model	Key modifications
Rating	Representation of Collyhurst Weir using a broad crested weir unit Skew in surveyed sections at the weir, IRKR01_1509 and at IRKR01_1558 accounted for
Rating A	Representation of Collyhurst Weir using a general weir unit Skew in surveyed sections at the weir, IRKR01_1509 and at IRKR01_1558 accounted for
Rating B	Representation of Collyhurst Weir using a broad crested weir unit Skew not accounted for at any surveyed cross-sections
Rating C	Collyhurst Weir represented using a broad crested weir unit, with the p2 value amended to represent the downstream cross-section bed level Skew in surveyed sections at the weir, IRKR01_1509 and at IRKR01_1558 accounted for
Rating D	Collyhurst Weir represented using a broad crested weir unit Skew in surveyed sections at the weir, IRKR01_1509 and at IRKR01_1558 accounted for – however using a slightly smaller skew angle than in previous models
Rating E	Collyhurst Weir represented using a broad crested weir unit, with the p2 value amended to represent the downstream cross-section bed level (as in Rating_15c.dat) Skew in surveyed sections at the weir, IRKR01_1509 and at IRKR01_1558 accounted for to the same extent as in Rating_15d.dat
Rating F	Skew at surveyed section IRKR01_1558 accounted for IRKR01_1509 taken from the 2021 Interim model, with a width of 22.61m; Collyhurst Weir taken from the 2021 Interim model, represented using a general weir unit, with a breadth of 21.3m (from 2019 weir crest survey) and elevation of 29.31mAOD
Rating G	Skew at surveyed section IRKR01_1558 and IRKR01_1509 accounted for Collyhurst Weir taken from the 2021 Interim model, represented using a general weir unit, with a breadth of 21.3m (from 2019 weir crest survey) and elevation of 29.31mAOD
Rating H	Collyhurst Weir represented using a broad crested weir unit Skew at surveyed section IRKR01_1558 accounted for IRKR01_1509 taken from the 2021 Interim model, with a width of 22.61m
Rating I	Collyhurst Weir represented using a general weir unit, with the skew of the weir not accounted for Skew at surveyed cross-sections IRKR01_1558 and IRKR01_1509u accounted for
Rating J	Collyhurst Weir represented using a general weir unit, with the skew of the weir not accounted for, and using a modular limit of 0.6 Skew at surveyed cross-section IRKR01_1558 accounted for IRKR01_1509 taken from the 2021 Interim model, with a width of 22.61m
Rating K	Collyhurst Weir represented using a general weir unit, with the skew of the weir not accounted for, and using a modular limit of 0.7 Skew at surveyed cross-section IRKR01_1558 accounted for IRKR01_1509 taken from the 2021 Interim model, with a width of 22.61m
Rating L	Collyhurst Weir represented using a general weir unit, with the skew of the weir not accounted for, and using a modular limit of 0.8 Skew at surveyed cross-section IRKR01_1558 accounted for IRKR01_1509 taken from the 2021 Interim model, with a width of 22.61m

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Model	Key modifications
Rating M	Collyhurst Weir represented using a general weir unit, with a modular limit of 0.55, exponent of 1.6 and discharge coefficient of 1.65 Bank roughness increased to 0.065 Skew at surveyed cross-sections IRKR01_1558 and IRKR01_1509 accounted for
Rating N	Collyhurst Weir represented as a general weir unit, taken from the previous rating model NorthernGateway_FMT_BAS_2021_010_hyd_Collyhurst_weir_v1.dat Skew at surveyed cross-sections IRKR01_1558 and IRKR01_1509 accounted for

Figure 31 illustrates the gauge data, compared to the model runs outlined in Table 2. The most suitable 1D results were subsequently run in 1D-2D, allowing flow routes along the road to be captured.

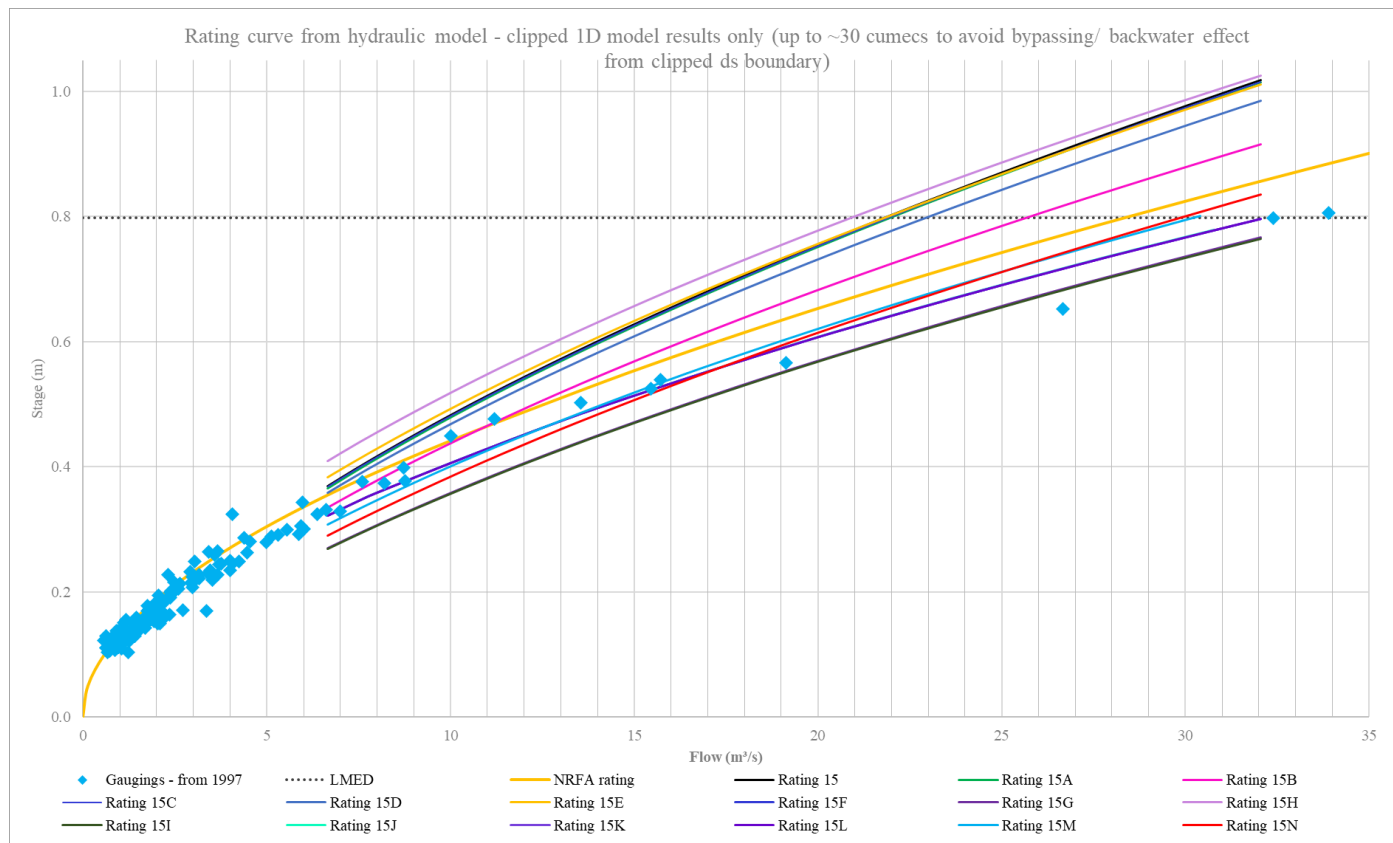


Figure 31: Performance of the 1D only rating models compared to the observed recent gauge data

Ratings F, J, L and M were considered to provide good fits to the observed gauge data, and as such the edits made to the representation of the river channel around Collyhurst Weir, in addition to the weir itself, were copied into the full 1D-2D model. The results are shown below, in Figure 32. While the ratings perform to a similar degree when fitting to the lower observed gauge data, Rating F is considered to provide the best fit to the higher recorded gauge data.

To best match the empirical data, therefore, it was determined that the cross-section immediately upstream of the weir should match the weir crest, rather than surveyed section BL5. Due to its location between 1m and

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4m upstream of the weir (depending on whether measured at the centre of the crest or the bank), cross-section BL5 represents a narrower channel than is observed immediately upstream of the weir; as a result, the section constrained the channel to a greater extent than in reality, leading to higher water levels for a given flow than the empirical data suggests, while also not representing the channel effectively (shown in Figure 33). It was therefore considered that the 2022 survey insufficiently captured the channel width upstream of the weir, thus requiring the 2019 survey to be used. This unit was therefore replaced by the original cross section, without accounting for skew, which provided a good match to empirical data. The original cross-section was taken from survey completed in 2019; the 2019 survey also provided a full cross-section of the weir, including bank levels in csv format, compared to the survey taken in 2022 which provided only values along the crest of the weir in drawing format rather than in a csv. The crest level of the weir is consistent between the 2019 and 2022 survey.

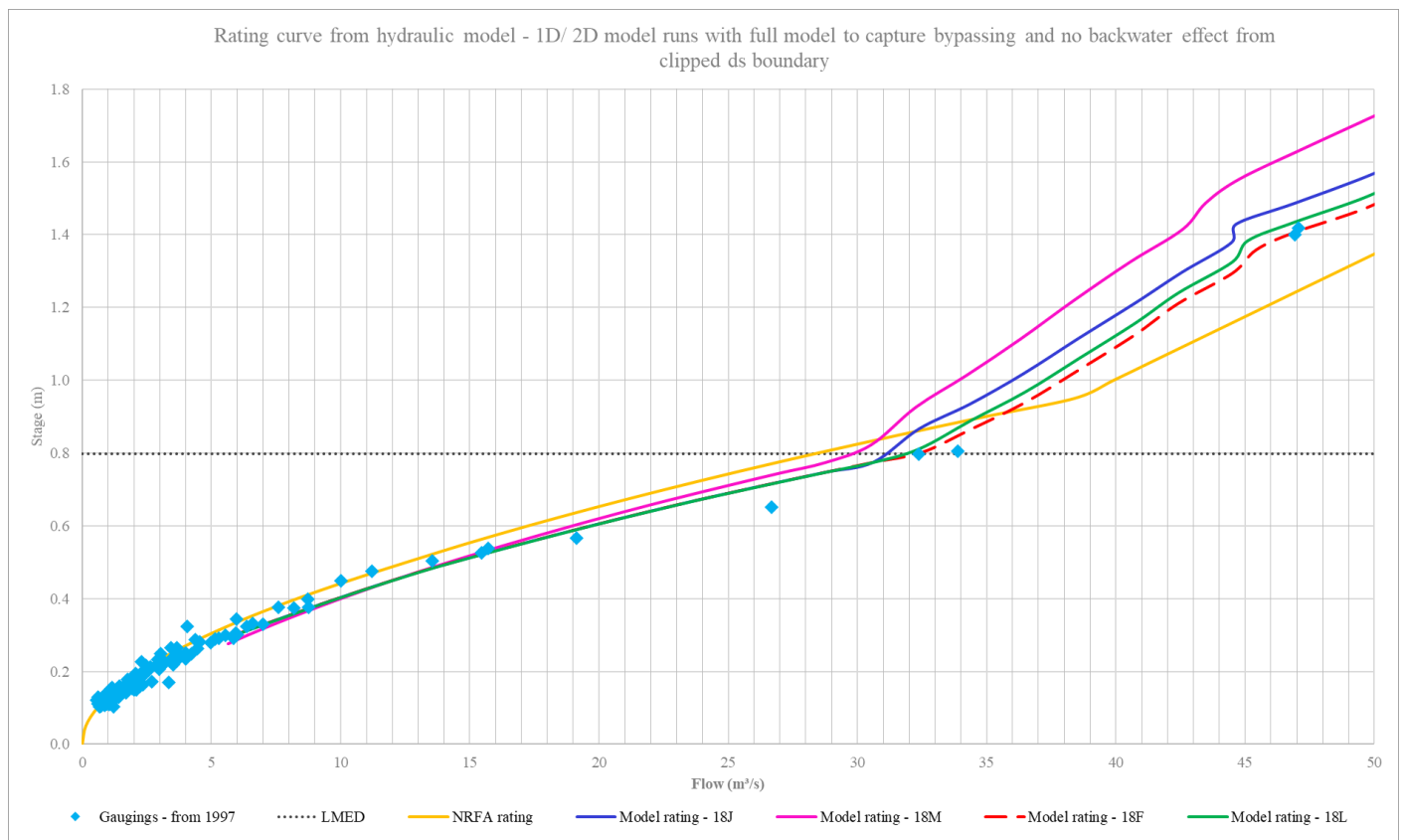


Figure 32: Comparison of the full 1D-2D model results with recent observed gauge data.

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Figure 33: Location of Collyhurst Weir, and associated cross-sections surveyed in 2019 and 2022.

Figure 27 represents the location of the surveyed cross-sections with the context of Collyhurst Weir, clearly demonstrating the reduction in channel width downstream of the weir; the spacing of the surveyed cross-sections was considered to be suitable to ensure that the model represented this narrowing. The dominant floodplain flow paths at this location are tied to overtopping of the right bank of the channel downstream of the weir, and the function of Collyhurst Road as a flow route for out-of-bank-flow. This flow route is therefore represented in the 2D model, and was captured during the rating exercise using 2d_po lines. Further detail about model results and flood mechanisms can be found in Section 5.

The changes around Collyhurst Weir made to the Rating F model, as described above, were incorporated into the 2022 Baseline model, which was run using the subsequently updated 2022 hydrology; a comparison of the FEH statistical peak flow with the Baseline modelled results, at Collyhurst Weir, is shown in Table 3.

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Table 3: Results from the Baseline model, when run using the 2022 hydrology at Collyhurst Weir. The FEH statistical peak flow is also shown, in addition to the scaling factor used in the model. The modelled results account for the in-channel, 1D model results extracted at node IRKR01_1039, in addition to the 2D floodplain flow, captured using 2d_po lines Q LB and Q RB. Since the hydrology updates have been completed, and accepted, there have been updates to the Baseline hydraulic model, and so it should be acknowledged that the results presented in the hydrology reporting may differ slightly when compared to results extracted from the most recent iteration of the Baseline model.

Return Period	FEH Statistical Peak Flow (m ³ /s)	Scaling factor	Baseline Modelled Peak Flow (m ³ /s)
20yr	50.5	0.912	50.5
30yr	53.6	0.87	53.8
100yr	63.4	0.74	63.4
100yr, 2020 climate change allowance	71.0	0.83	70.7
100yr, 2050 climate change allowance	75.4	0.895	75.7
100yr, 2080 climate change allowance	85.6	1.02	85.8
1000yr	105.1	0.76	104.5

3.4 Outstanding Environment Agency review comments

Several comments made in the Environment Agency review of the 2021 Interim Model remained outstanding when work on the 2022 Baseline Model commenced. The updates to the model to address these comments are described here, noting that model sensitivity tests are described in Section 5.1.

The 2022 Baseline Model was run using the updated 2022 hydrology, as described above, in Section 3.3; the model was run for a greater number of return periods than the 2021 Interim Model, namely the 20yr, 30yr, 100yr and 1000yr events. The 100yr event was also run for the 2025, 2050 and 2080 climate change epochs. The model was run for the 9.5hr duration event, summer season.

The 2021 Interim Model was considered to be unstable in the 1000yr event, as shown by the hydrograph in Figure 34 taken from IRK_1.13, the location of the gauging station close to Collyhurst Weir, with clear instabilities near the peak of the event. When running the 2022 Baseline Model with the updated hydrology, the instabilities in the hydrograph are no longer present, as shown in Figure 35. This is a result of the lower FEH flow estimates in the hydrology updates, described in VNR-ARP-00-YYY-RP-CH-0001_Flood Estimation Report.

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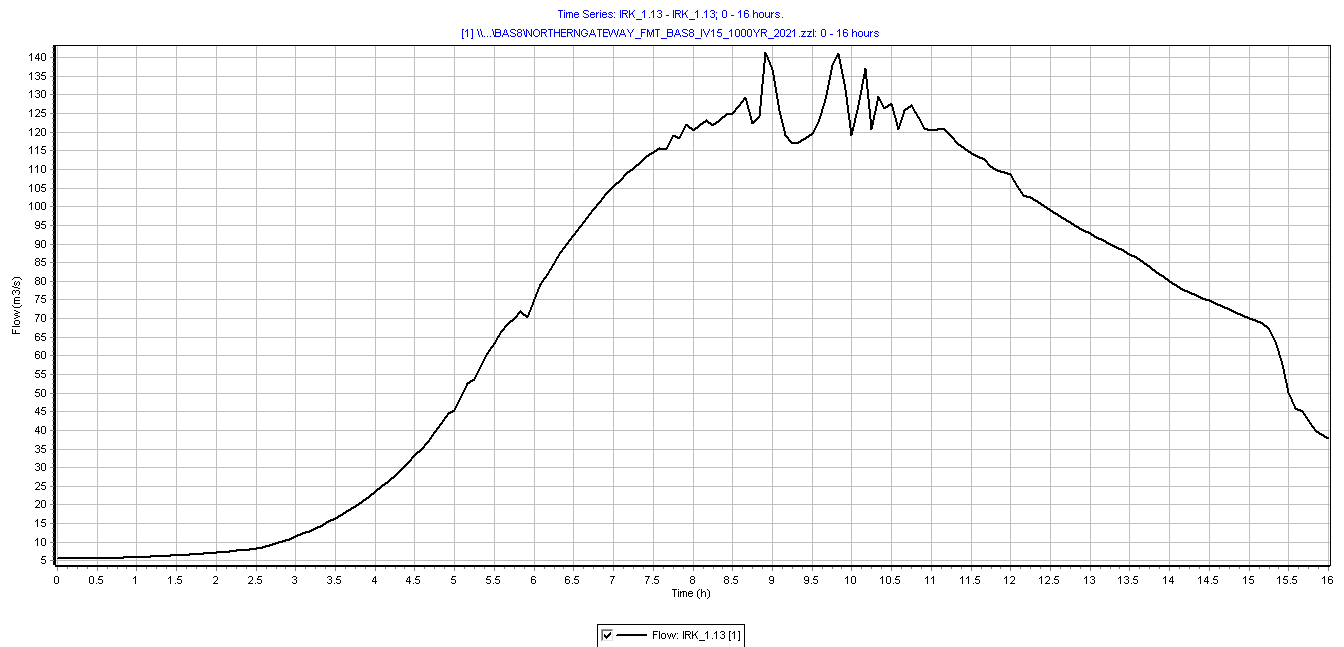


Figure 34: Hydrograph extracted from the 2021 Interim Model, for the 1000yr event at IRK_1.13, the site of the gauging station upstream of Collyhurst Weir

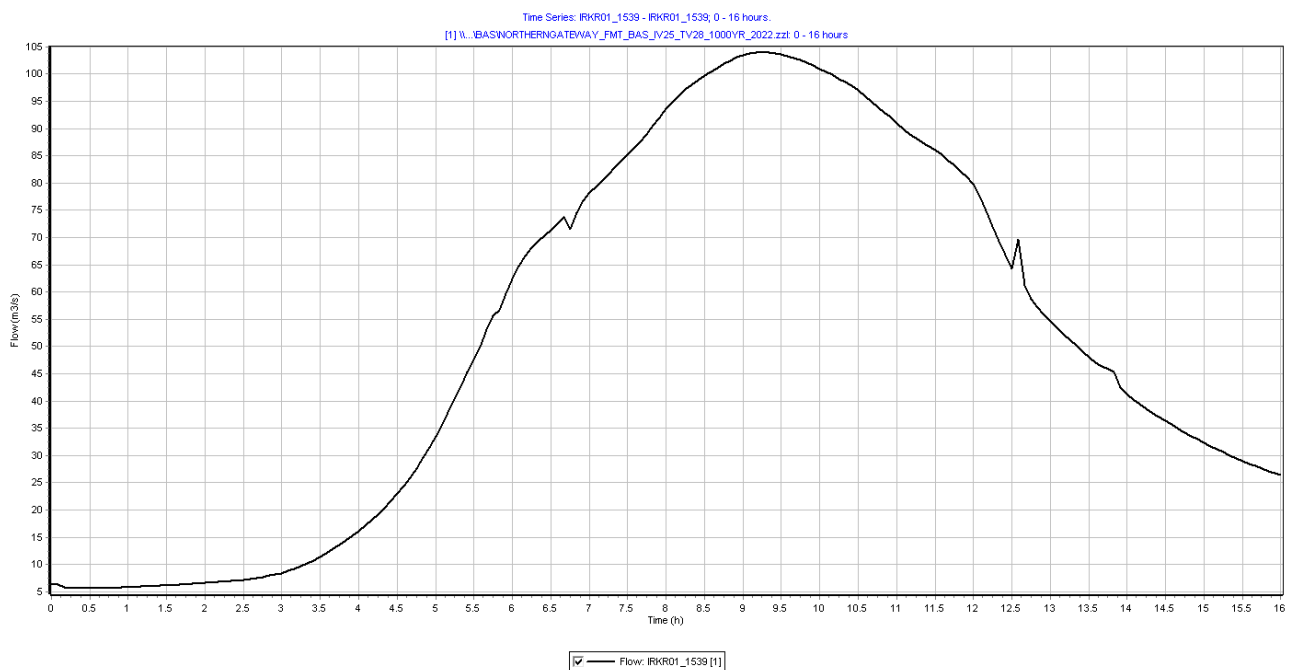


Figure 35: Hydrograph extracted from the 2022 Baseline model, using 2022 hydrology, for the 1000yr event at IRKR01_1539, at the site of the gauging station upstream of Collyhurst Weir

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The two roughness layers used in the 2D domain of the baseline model, *2D_mat_Irk.shp* and *2d_mat_FMT_NorthernGateway_2021_010_R.shp*, were merged into a single layer, *2d_mat_FMT_NorthernGateway_2021_011_R.shp*. The roughness values applied to the 2D domain have not been updated, however they are considered appropriate based on OS Open Map Local data and online imagery. The justification for the use of roughness values in the additional surveyed sections can be found in Section 3.1.4.

3.4.1 2022 Baseline model review comments

Following the review of the 2021 Interim Model, an initial submission of the 2022 Baseline model was made. Comments in the 2022 Baseline model review have been addressed and are outlined below.

Detailed EA comments and Arup responses are given in document *FT-OCT-3 EA 2022 Baseline Model Review_Arup_1st_response.xls* dated 11/11/22.

Additional interpolates have been included to improve node spacing, and the addition of panel markers to improve conveyance. In response to the review, the soffit shape of the USBPR unit representing Union Bridge was updated to “ARCH”, and the footbridge at MOST01_4980A was removed, as this was represented as an orifice which was causing two instances of model non-convergence.

Warnings of different GIS projections and Water Level Lines not crossing a network line have been corrected.

Checks were undertaken throughout the model to ensure that top of bank levels assigned in the 1D model matched those being stamped in the 2D model by z-lines.

Attempts to improve the “dVol” signature were made, as follows:

- The alignment of boundary lines between the 1D and 2D model domains were updated where model bank lines were not following LiDAR data correctly – subsequent realignment updates were made to inactive code polygons and z-line bankline shapefiles;
- The location of the MOST01_000H confluence was realigned in 2D, as it was located in the incorrect place; the left bank of the cross-section was raised to 33.241mAOD, as shown on Google Earth to match the River Irk cross-section. The junction with the River Irk was moved downstream of the bridge at IRKR01_1788, as per aerial imagery;
- The spill into the 2D domain at MOST01_0177 was updated to correctly represent a wall above the culvert entrance, as can be seen in Google Streetview; prior to this update, flow was overtopping the culvert entrance into cells set at an incorrect level;
- The footbridge in St Catherine’s Wood, at IRK_1.09, was extended in 1D to reduce 2D flooding which was potentially a cause of an instability; realignments were made to the necessary 2D shapefiles, and the soffit shape of the USBPR unit representing the footbridge was updated to “ARCH”;
- 1D-2D boundary connections at Union Bridge were re-schematised, giving an additional set of CN lines delineating the cells assigned to the level of the bridge parapet, from those assigned to the bank level;
- The Manning’s n roughness value of the spill over Union Bridge was updated from 0.025, to 0.10, in an attempt to reduce mass balance errors occurring where flow spills out of bank, and onto the bridge deck. Deck levels were also altered to align with the most up to date topographic survey;
- A roughness patch, set at a Manning’s n of 0.065, was added on the left bank of the Irk, downstream of Union Bridge, to attempt to slow the high, out of bank velocities, where flows rush to re-enter the

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channel – this roughness value was not raised any higher, to prevent the inadvertent diversion of flow south, along Dantzic Street;

- The face of the Aspin Lane culvert was realigned in the 2D domain to include the height of the culvert face, reducing mass balance errors. The threshold of the commercial building on the right bank of the channel, next to the culvert face, was added, based on BAM's survey;
- The orifice flow transition distance at the IRK_1.16 structure was adjusted from 0.1m, to 0.05m, to attempt to reduce an instability caused by the spill at the structure becoming active during events less than the 100yr event, with a climate change allowance to the 2050 epoch. The spill of the structure was also missing the brick wall on the left side of the channel, which formed part of the bridge parapet – this was updated using available survey.

Whilst the attempts to smooth the dVol curve were able to calm mass balance issues in the 2D domain within the study focus area, the dVol plot remained largely unchanged. By utilising the .zxx output from Flood Modeller, this supplementary results file shown in Figure 36 highlighted the location of erratic oscillations occurring between the 1D and 2D model domains. Oscillations on the upper Moston Brook, particularly in areas upstream of model node MOST01_4350, are likely to be largely responsible for the spikiness of the overall model dVol output plot. Plots from the same supplementary results file do not display any notable spikes, especially over the peak of the event through the downstream study area of interest. Consequently, it should also be noted that model results through the study area are not affected by instabilities in the Upper Moston Brook area of the model.

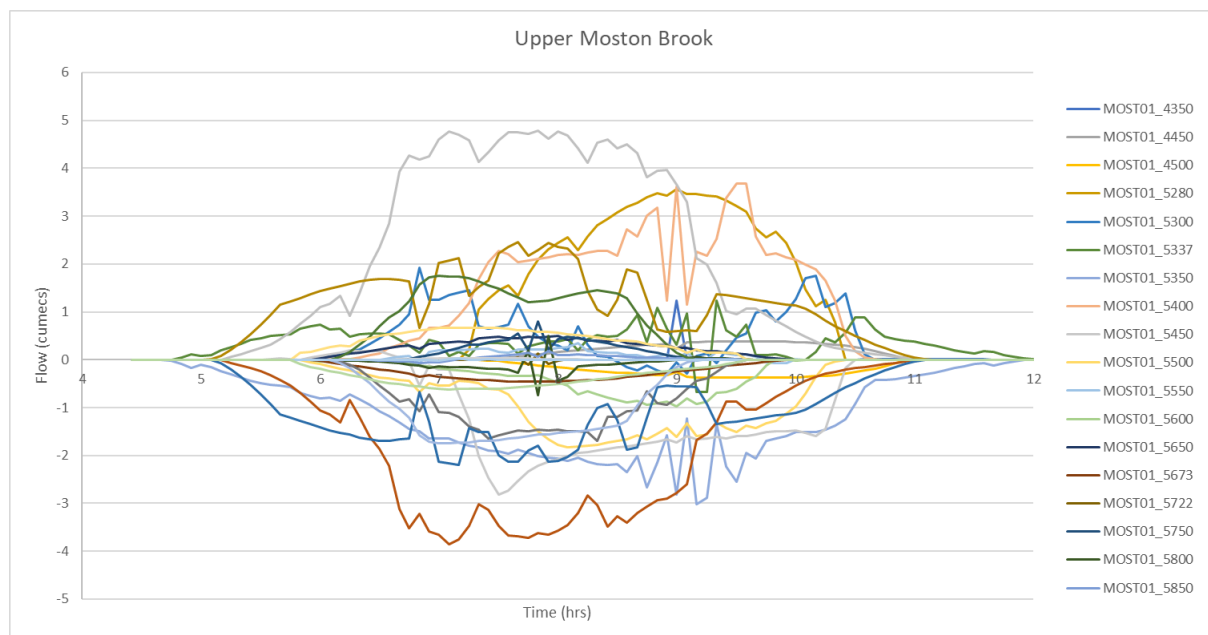


Figure 36: Flood Modeller supplementary results (Link Inflow) for Upper Moston Brook (1000yr event)

Union Plaza Wall

Several upstanding walls situated on the banks of the River Irk throughout the study area are included in the model. In absence of any formal structural assessments being made, these are assumed to be structural sound and could withstand the hydrostatic water loading from a flood event, however concerns were raised during the model review of the structural integrity of the Union Plaza Wall on the right bank upstream of Union Bridge. This brickwork wall looks to be the remains of a former building however no asset structural

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assessment has been undertaken to ascertain the strength of this approximate 85m length of wall. From historic images available from Google StreetView as shown in Figure 37, the wall has deteriorated in recent years. Sensitivity testing was undertaken to understand the change to flood risk/extents on the plots if this wall was not represented in the model and following discussions with the project team, it was decided that the Baseline model should not include representation of the Union Plaza Wall.

This stretch of upstanding wall at Union Plaza has been removed from the 1D and 2D models. Model nodes IRK01_0961 upstream to IRK01_0136 have had the wall shown in survey sections BL6 to BL11 removed, and the corresponding bank lines in the 2D model have been adjusted.



Figure 37 - Time lapse photo of the Union Plaza Wall taken from StreetView

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4. Assumptions

There are several key assumptions that have been made due to irregularities in geometry of existing structures:

1. The Aspin Lane culvert changes shape multiple times over its length, as discussed in Section 3.1.3. The model represents the most hydraulically restrictive downstream face, as well as the more significant changes within the culvert such that storage provided by the culvert itself is taken account of. Culvert outlet loss units have been used to represent the culvert shape changes, and as such, copies of culvert sections have been used to represent the upstream and downstream faces of the culvert where these shape changes occur, also allowing the model to run successfully. The application of loss units along the length of the culvert results in stepped headloss through the culvert. It is not thought that this methodology has an adverse effect on model results or one that propagates through the model.
2. Scotland Weir is represented using a regular spill unit, to ensure that the geometry of the weir is correctly included in the model. The geometry of the spill was taken from the survey undertaken in 2022, with a spill coefficient set at 1.7 to correctly represent the weir as a round-nosed horizontal-crested weir. The skew of the weir was also accounted for, leading to a reduction in the width of the surveyed weir from 19.41m to 13.72m. The wall to the left of the weir included as part of the survey has been included as part of the weir profile as this occupies a significant portion of the channel as it turns into the culvert downstream.

Non-default values were used in the Baseline model, in all modelled return periods, for the *Matrix Dummy* and *Global Matrix Dummy* coefficients to prevent the following 1D-solver error: "*E1196: Matrix numerically singular. iflag = -2*".

5. 2022 Existing condition Baseline results

The 2022 Baseline model was run for the 20yr, 30yr, 100yr and 1000yr; the 100yr was also run with a climate change allowance for the 2025, 2040 and 2080 epochs. Appendix A illustrates the modelled hydrographs for each of the hydrology inflow boundaries.

Figure 38 is a long section showing maximum water level for cross-sections between IRK_1.14 and IRKR01_0564. The long section demonstrates head loss at key structures, such as Union Bridge, Aspin Lane Bridge and Scotland Weir. Scotland Weir appears to not drown out in any modelled event, showing head loss over the weir in all return periods modelled; in the 20yr event, there is a 2.33m reduction in maximum water level between IRKR01_0579F (upstream of Scotland Weir) and IRKR01_0579G (downstream of Scotland Weir), which decreases to a 0.17m reduction in the 1000yr event. Similarly, the long section appears to show that the Aspin Lane Culvert is not a major hydraulic control on the River Irk, as a result of the high soffit levels (of up to 36.32mAOD), and large cross-sectional areas through the culvert system. Aspin Lane Bridge, however, is shown to be a significant hydraulic control on the river system, resulting from the large constriction which the structure places on flow; there is a reduction in soffit level from 35.38mAOD to 28.28mAOD at the culvert outlet. In the 1000yr event, the maximum water level at IRKR01_0660u, the conduit unit immediately upstream of Aspin Lane Bridge, is 30.65mAOD, falling to 29.92mAOD at IRKR01_0660d, the upstream conduit unit representing the bridge.

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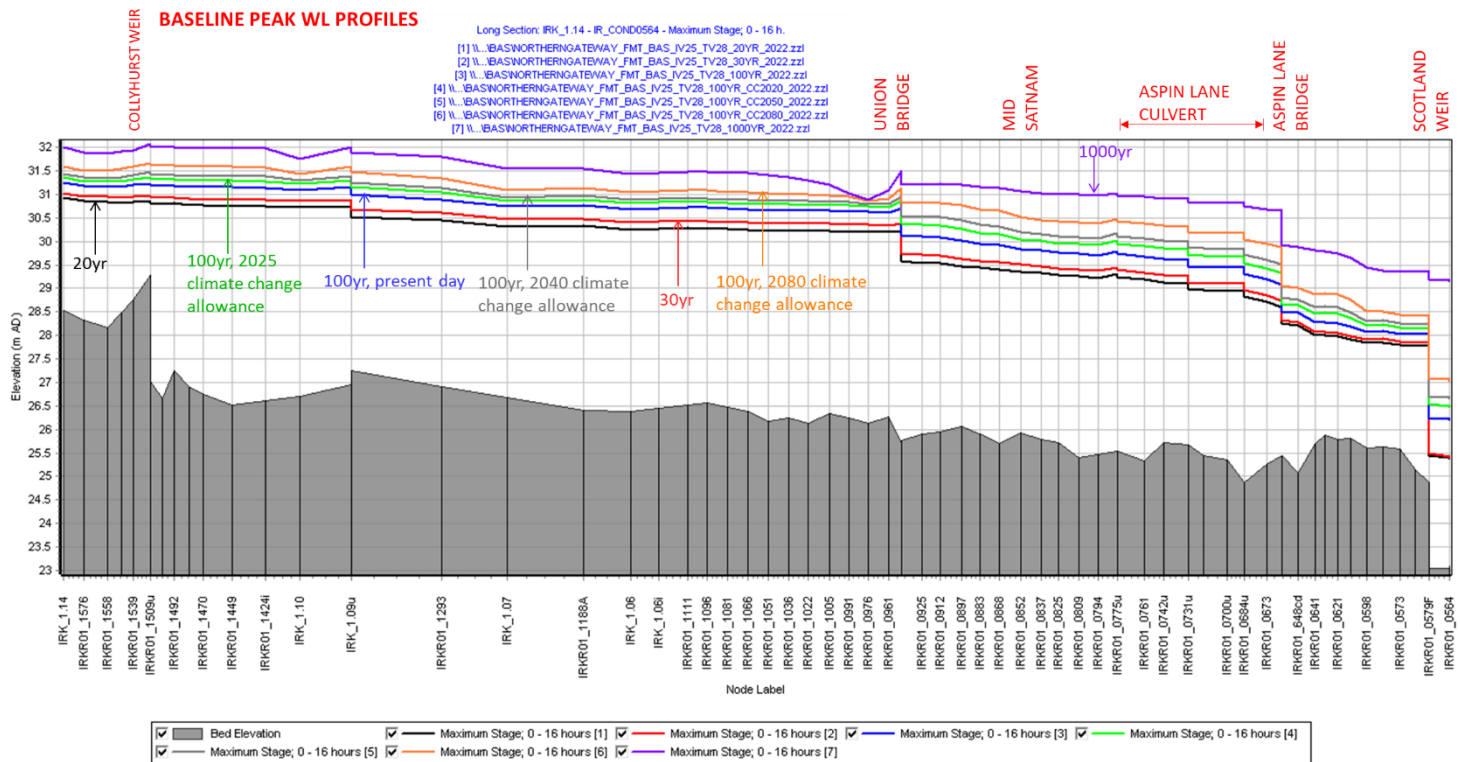


Figure 38: Long section from the 2022 Baseline model, illustrating maximum water level for a range of return periods, run using the 2022 hydrology

Figure 39 shows the updated flood extents for the 20yr, 30yr, 100yr and 1000yr events, using the 2022 Baseline model and 2022 hydrology. The flood extents have reduced since the previous modelling, based on the Interim 2021 Baseline model, as a result primarily of the implementation of the lower flows associated with the 2022 hydrology.

Figure 39 illustrates that the 20yr and 30yr events largely remain in-channel, particularly around Harpurhey Reservoirs in the upstream area of the model. Further downstream, there is some out of bank flow close to Collyhurst Weir; flow leaves the left bank of the channel downstream of the weir, and moves downstream along Collyhurst Road. As the updated Baseline model does not represent the wall along the right bank of the channel upstream of Union Bridge, there is some out of bank flow here; flow also leaves the left bank of the channel upstream of the bridge, flowing along Dantzic Street to re-enter the channel. Figure 40 illustrates these two key flood mechanisms in the 20yr event, which are also demonstrative of mechanisms in the 30yr event.

Flood mechanisms in the 20yr and 30yr events, as shown in Figure 40, are also present in the 100yr, 100yr with climate change allowances, and 1000yr events. Figure 39 illustrates a considerable flood extent in the 1000yr event; in addition to flow leaving the channel upstream of Collyhurst Weir, flows leave the Moston Brook, and the River Irk upstream of the confluence with the Moston Brook, and flows along Collyhurst Road. This provides a continuous flow path also along Dantzic Street, which is similarly seen in the 100yr events with climate change allowances. Flows leave the channel on the right bank of the River Irk between the Moston Brook confluence and Collyhurst Weir, in the 100yr events, with climate change allowances for the 2040 and 2080 epochs, in addition to the 1000yr event. Similar to the mechanisms illustrated in Figure 40, flow leaves the left and right banks of the channel upstream of Union Bridge, and flows upstream and

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downstream, both along the road networks and across the floodplain. Figure 41 demonstrates the additional key flood mechanisms in the 1000yr event, which are broadly applicable in the 100yr events with climate change allowances.

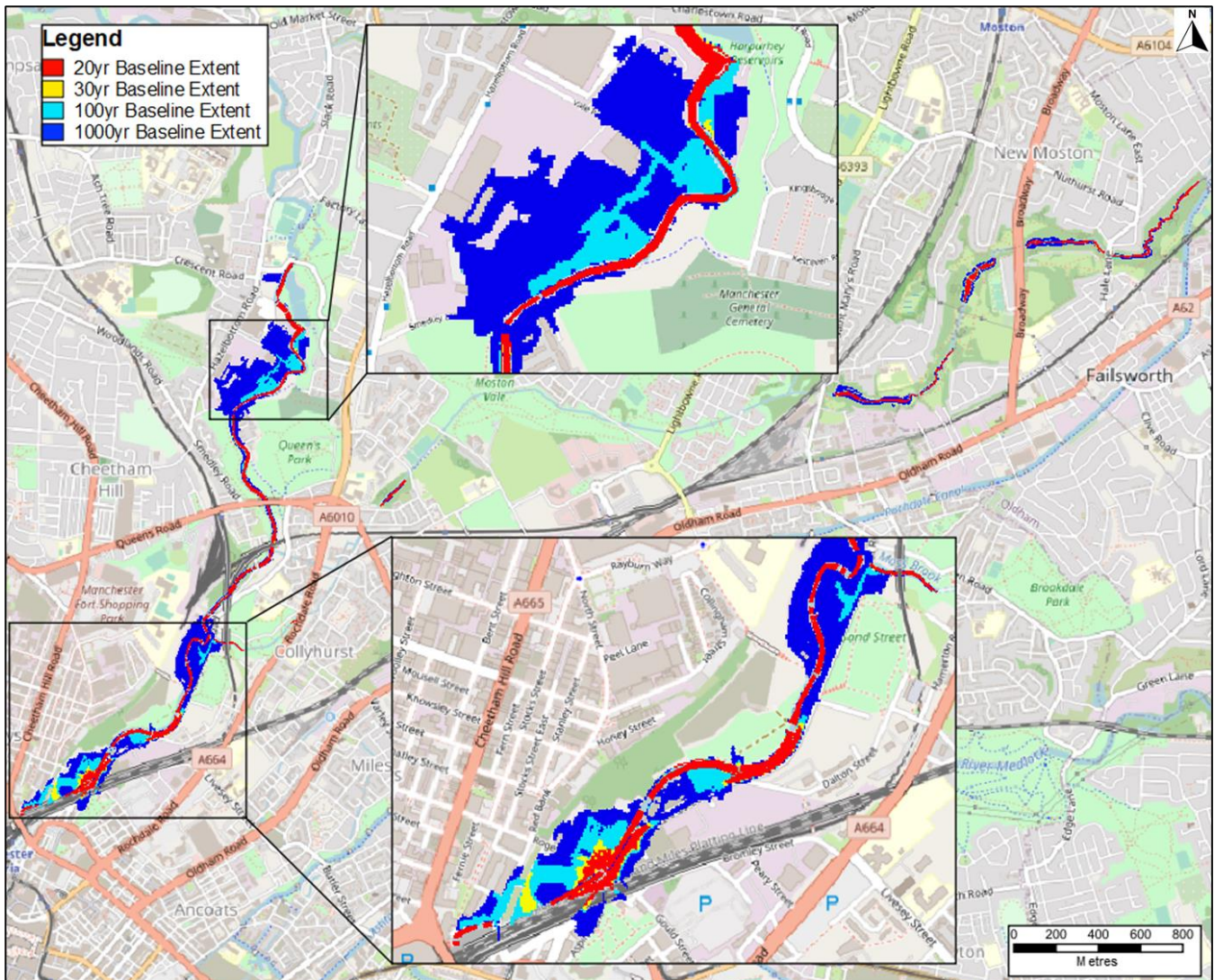


Figure 39: Updated flood extents for the 20yr, 30yr, 100yr and 1000yr events, based on the 2022 Baseline model and 2022 hydrology.

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Figure 40: Key flood mechanisms around Collyhurst Weir and Union Bridge in the 20yr event, also demonstrative of flow paths in the 30yr event. The black arrows indicate vector velocity, showing flows leaving the channel downstream of Collyhurst Weir and upstream of Union Bridge



Figure 41: Key flood mechanisms around Collyhurst Weir and Union Bridge, in the 1000yr event, but also broadly applicable to the 100yr events with climate change allowances. Black arrows indicate vector velocity, clearly showing the flow along Collyhurst Road and Dantzie Street

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5.1 Model sensitivity tests

A full suite of model sensitivity tests was completed for the 100yr event, comprising of the addition of culvert outlets along Moston Brook, increases and decreases to inflows, increases and decreases to roughness, increases and decreases to the downstream boundary, increased 2D grid resolution, grid rotation, and the use of the “*DfloodB*” value in .IEFs. Following the decision to remove the Union Plaza wall as part of the Baseline model, a sensitivity test has been included to demonstrate the change to flood risk if the wall remains in the model as discussed in Section 3.4.1.

The “*DfloodB*” value is needed in the model Advanced Parameters to ensure that the model initialises in Flood Modeller Pro. Using the default value of 10, rather than 15 as is used, leads the model to fail with the following error: “*** error E1577 *** at label: MOST01_0249D, Bridge soffit is more than 10m above cross section”. Similarly, the introduction of culvert outlets along the Moston Brook, replacing spill units at MO_1504A and MO_0655 caused significant model instability.

Figure 42 shows a long section of the 2022 Baseline model results, compared to results from the inflow and grid resolution sensitivity tests. The increases and decreases to the inflows led to an expected increase and decrease in water level through the long section, respectively. The 20% increase to the inflows led to a maximum of a 0.43m increase in peak water level between IRK_1.14 and IRKR01_0564, presented in the long section below, while the 20% decrease to the inflows led to a maximum decrease in peak water level of 0.61m through the same long section. The increases and decreases achieved by altering the inflows is minimised downstream of Scotland Weir; at section IRKR01_0579d. Immediately downstream of Scotland Weir, the 20% increased inflows led to an average of a 0.08m increase in peak water level, with a 20% reduction in inflows leading to an, on average, 0.07m decrease in peak water levels. This indicates that Scotland Weir is a large control on the behaviour of the watercourse acting as a hydraulic break, with the downstream boundary and influence of the River Irwell exerting a control on the River Irk downstream of the weir.

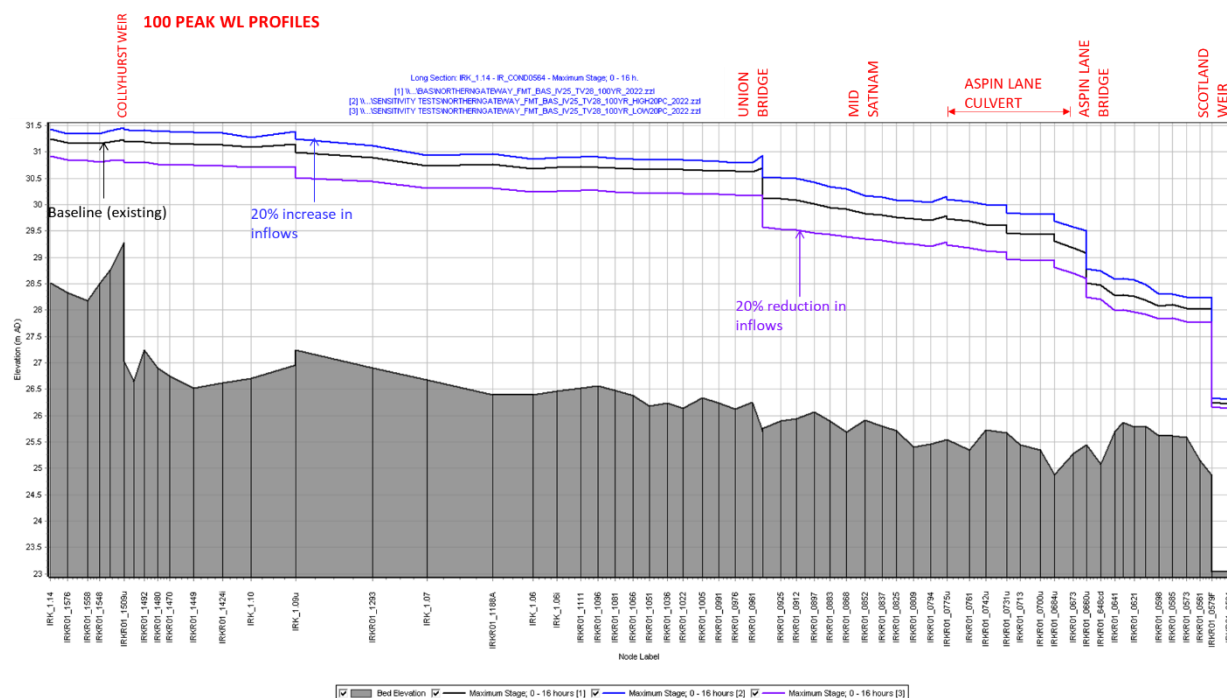


Figure 42: Long section of 1D results, showing the 2022 Baseline 100yr results compared to the results of the sensitivity tests increasing and decreasing inflows by 20%.

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The Baseline model at present uses water levels extracted from the Manchester Ship Canal model to represent the downstream boundary at the River Irk – River Irwell confluence; the downstream boundary used in the 20yr Baseline event for instance, is based on 20yr water levels extracted from the Manchester Ship Canal model, while the downstream boundary implemented in the 1000yr Baseline event is based on 1000yr Manchester Ship Canal model water levels. Figure 43 shows a long section of the 2022 Baseline model results, compared to results from the downstream boundary tests; high and low downstream boundary tests were undertaken. The “Low downstream boundary” test was run with the 100yr 2022 hydrology inflows, but additionally took the downstream boundary used for the 20yr model event, originally from the 20yr event results for the Manchester Ship Canal model. The “High downstream boundary” test was also run with the 100yr 2022 hydrology inflows, with the 100yr event downstream boundary scaled to a peak of 28.37mAOD, taken, from LiDAR to be bankfull in the River Irwell (an increase in boundary water level of approximately 2.35 m).

Figure 43 illustrates that the influence of the low downstream boundary is significantly smaller than the influence of the high downstream boundary, with Scotland Weir the upstream extent of the differences in water levels achieved by the low downstream boundary. There is a 0.7m reduction in water level at Scotland Weir when using the low downstream boundary, compared to the Baseline model.

The high downstream boundary causes an increase in water levels of 2.22m at the downstream face of Scotland Weir compared to the Baseline model; this increase, however, is significantly reduced upstream of the key hydraulic structures along the River Irk, namely Scotland Weir, Aspin Lane Bridge and Union Bridge. At the downstream face of Collyhurst Weir, for instance, there is a negligible change in peak water levels. The sensitivity of the model to the downstream boundary at present therefore appears to be somewhat muted by the influence of Scotland Weir over water levels in the model, however may be significant if future works were undertaken to remove or modify Scotland Weir significantly (modifications to the weir are currently being proposed as part of the Victoria North River and Flood Alleviation Scheme), perhaps increasing the frequency with which the weir is drowned out.

The “High downstream boundary” sensitivity test represents a bankfull event on the River Irwell, however the levels of this event are below the levels extracted from the Manchester Ship Canal model 1000yr event. While the results presented in Figure 43 show that the sensitivity test does impact water levels along the River Irk, although the impact is minimised upstream of Scotland Weir, it is considered that the current approach to the downstream boundary remains appropriate, as a result of the consistency achieved in the Baseline model between the lower and higher magnitude events while using the approach. Similarly, at high magnitude events, such as the 1000yr event, the current approach remains conservative.

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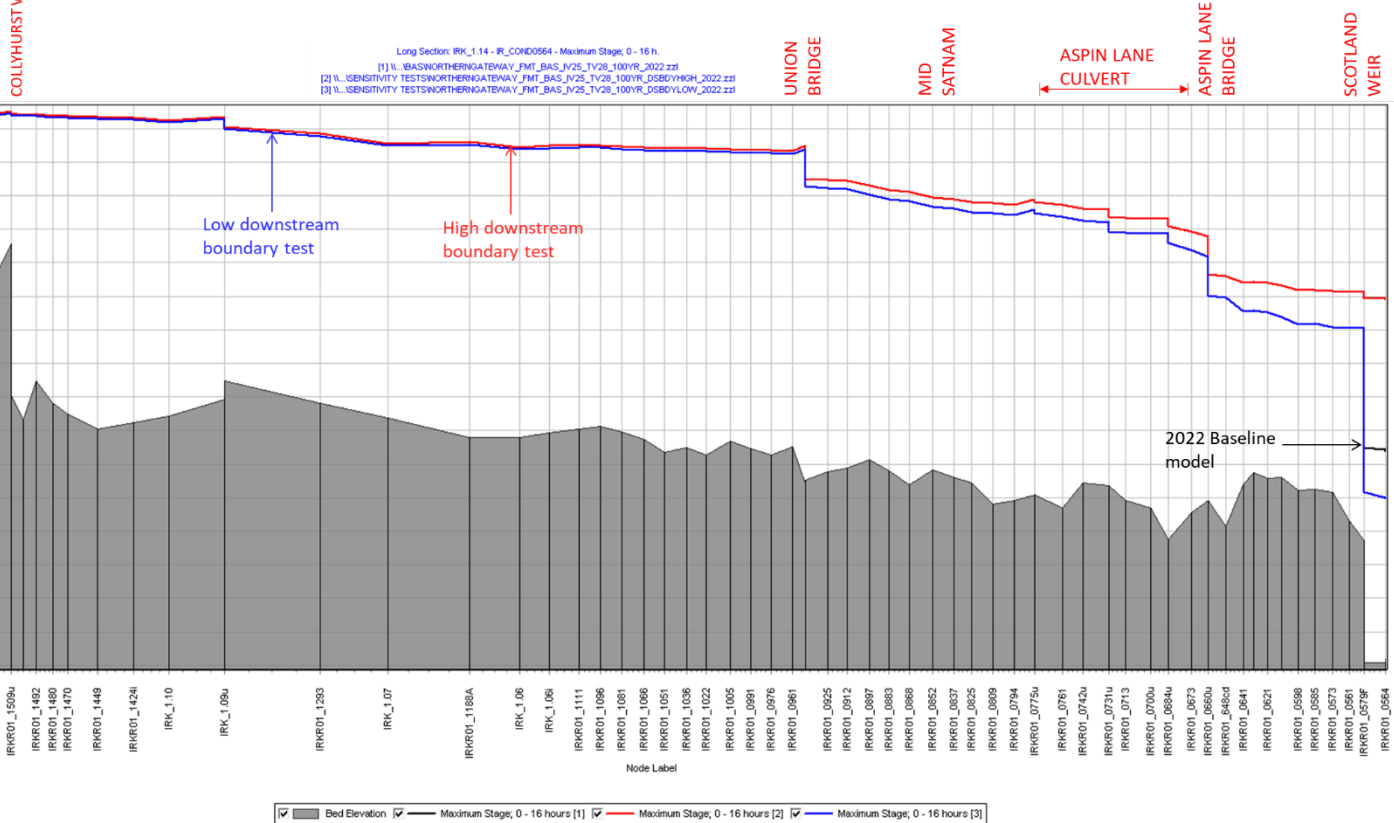


Figure 43: 2022 Baseline model 100yr results, compared to results of the downstream boundary sensitivity tests.

Figure 44 similarly shows the results of the 2022 Baseline model, compared to sensitivity tests with a 20% increase, and 20% decrease, in roughness in the 1D and 2D domains. Overall, increasing the roughness of the model by 20% led to, on average, a 0.07m increase in peak water levels through the site of interest, shown in the long section below; reducing the roughness of the model led to an average of a 0.11m reduction in peak water level. This pattern is expected, as a result of the increased attenuation of water and lower water velocities associated with an increased in-channel, bank and floodplain roughness, with a reduced level of attenuation resulting from a reduction in roughness. The maximum increase in peak water level resulting from increasing the roughness of the model was 0.17m, while the maximum reduction in peak water level caused by the reduction in model roughness was 0.24m; both of these values were achieved at node IRK_1.14, at the upstream extent of the site of interest. Downstream of Scotland Weir, there is a negligible difference between the Baseline model and the roughness models; the average change downstream of the weir achieved by the roughness models is 0.004m, potentially a result of the influence of the downstream boundary, as described above.

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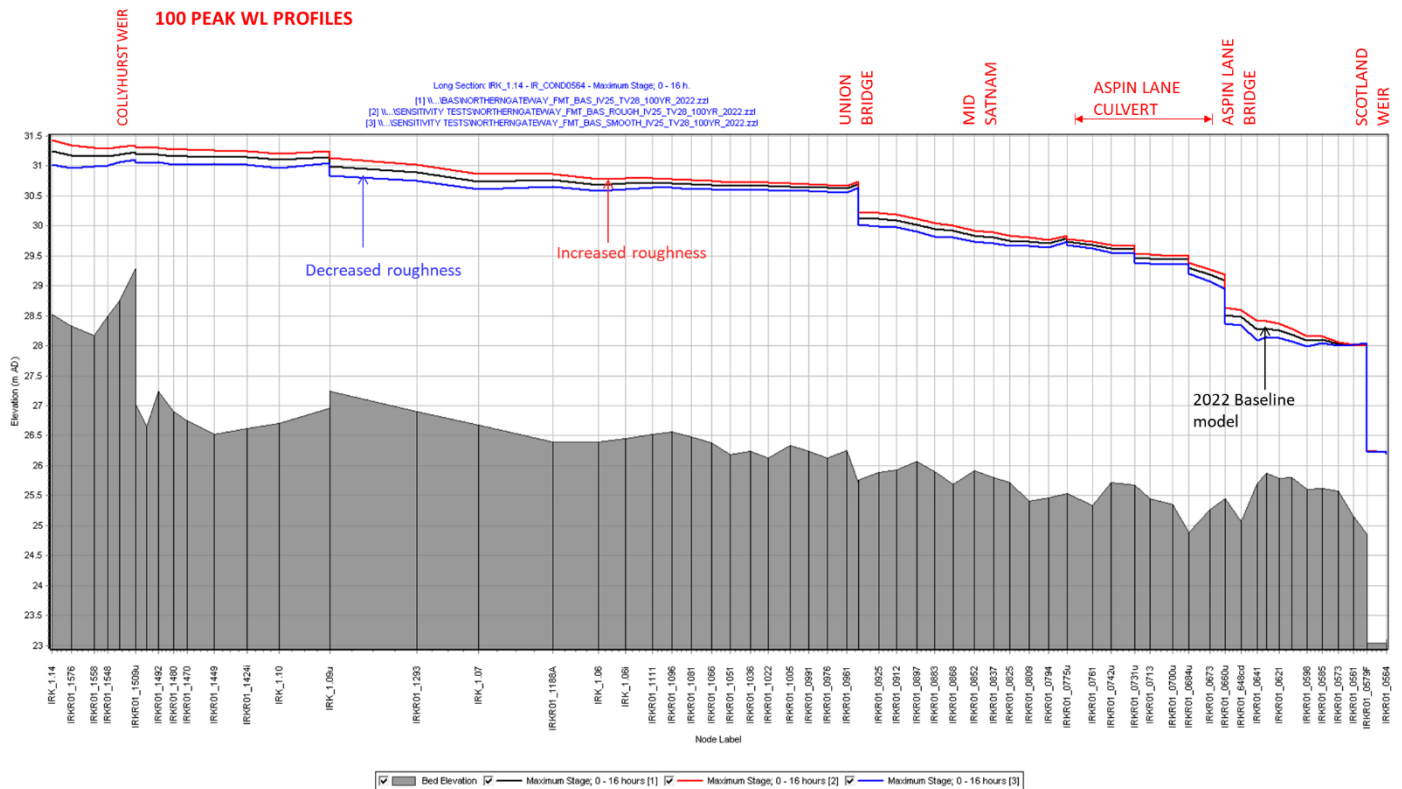


Figure 44: Baseline model 100yr results, compared to results from sensitivity tests increasing and decreasing model roughness by 20%

The use of a 2m grid resolution in the 2D domain, rather than a 4m resolution, similarly has an impact on in-channel water levels, as demonstrated by Figure 45. Through the long section, between cross-sections IRK_1.14 and IRKR01_0564, there is an average reduction in peak water level of 0.04m when using a 2m grid resolution, compared to a 4m grid resolution. Union Bridge appears to exert a large control over water levels when using a 2m grid resolution; at IRKR01_0961, 20m upstream of the bridge, there is a reduction in peak water levels of 0.18m, while 16m downstream of the bridge, at IRKR01_0925, there is a reduction in peak water levels of 0.03m, when compared to using a 4m grid. Figure 45 also illustrates the difference between the baseline model and the grid rotation sensitivity model – which has a 45° rotation of the grid, so that it is orientated north-east to south-west – showing a very minimal impact on water levels through the study site, with an average change of 0.02m caused by the rotated grid. Upstream of Collyhurst Weir, rotating the grid to have a north-east to south-west orientation causes a negligible increase in peak water levels, with an increase of less than 0.01m. Downstream of Collyhurst Weir, rotating the grid orientation causes a decrease in peak water levels, however the average decrease is 0.02m, when compared to Baseline. Figure 46 shows that there is an increased flood extent upstream of the study site, close to Harpurhey Reservoirs, when compared to the Baseline, caused by the 2D grid orientation and dominant overland flow mechanisms in the area.

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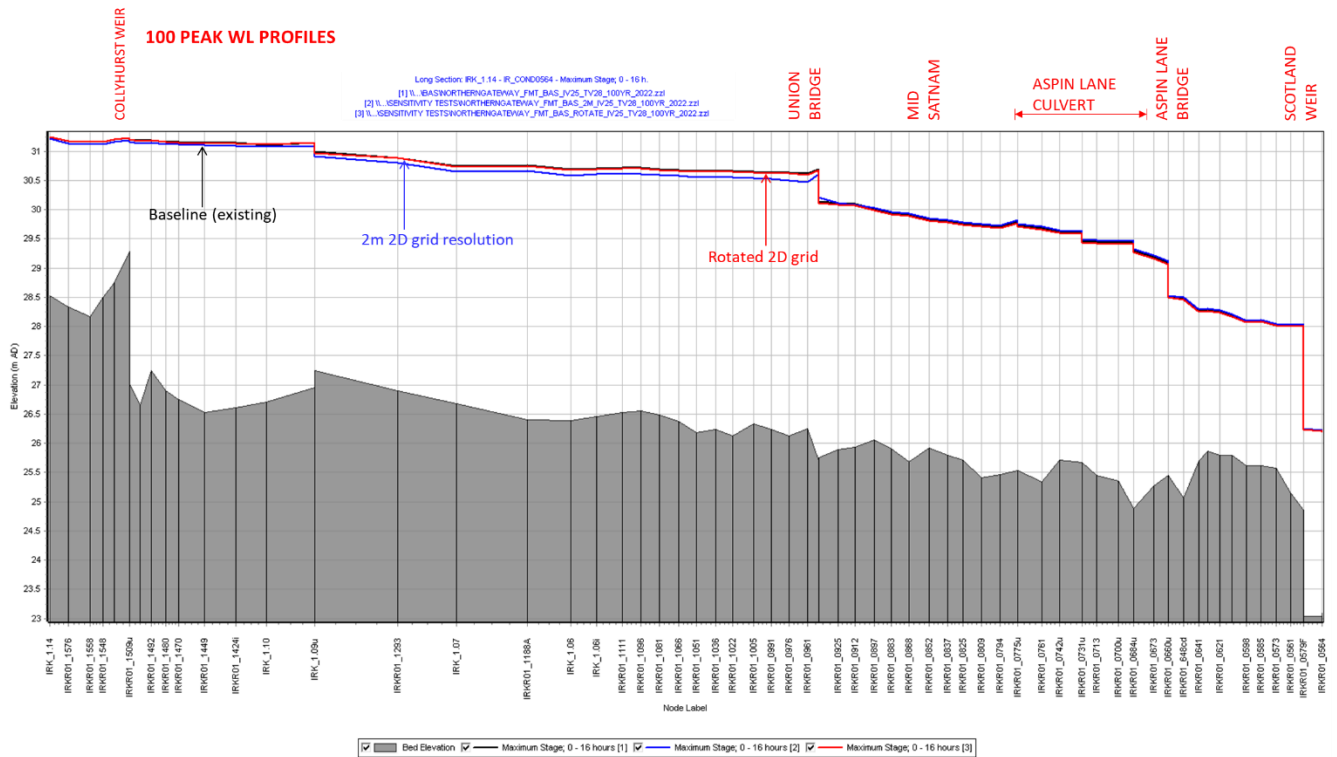


Figure 45: Baseline model 100yr results, compared to results from sensitivity tests decreasing the 2D grid resolution and rotating the 2D grid

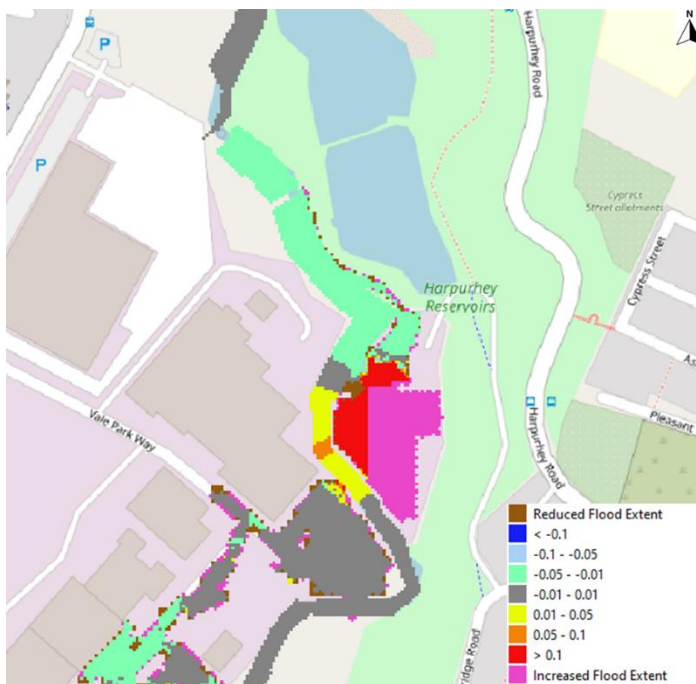


Figure 46: Impact map based on the 100yr events for the 2022 Baseline model, compared to the model with a rotated grid, clearly showing the increased extent close to Harpurhey Reservoirs, caused by the grid rotation.

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The sensitivity test to include the Union Plaza wall shows an increase in water levels in the channel of 0.03m immediately upstream of Union Bridge, as shown in Figure 47. This increase in water levels extends approximately 780m upstream of the bridge, at which point the difference between maximum in-channel water levels in the Baseline model, and sensitivity test with the wall at Union Plaza, is below 0.01m. Figure 48 is an impact map showing the difference in flood extents and flood levels between the Baseline model, and "With wall" model. Whilst there are minimal changes to flood extents and depths along the left bank at Dantzie Street, there are areas of reduced flood extent on the right bank, when the wall at Union Plaza is included in the model. Within the plot areas of the 2D domain around Roger Street for the "With wall" sensitivity run, there is a maximum reduction in peak depths of c0.058m during the 100yr event.

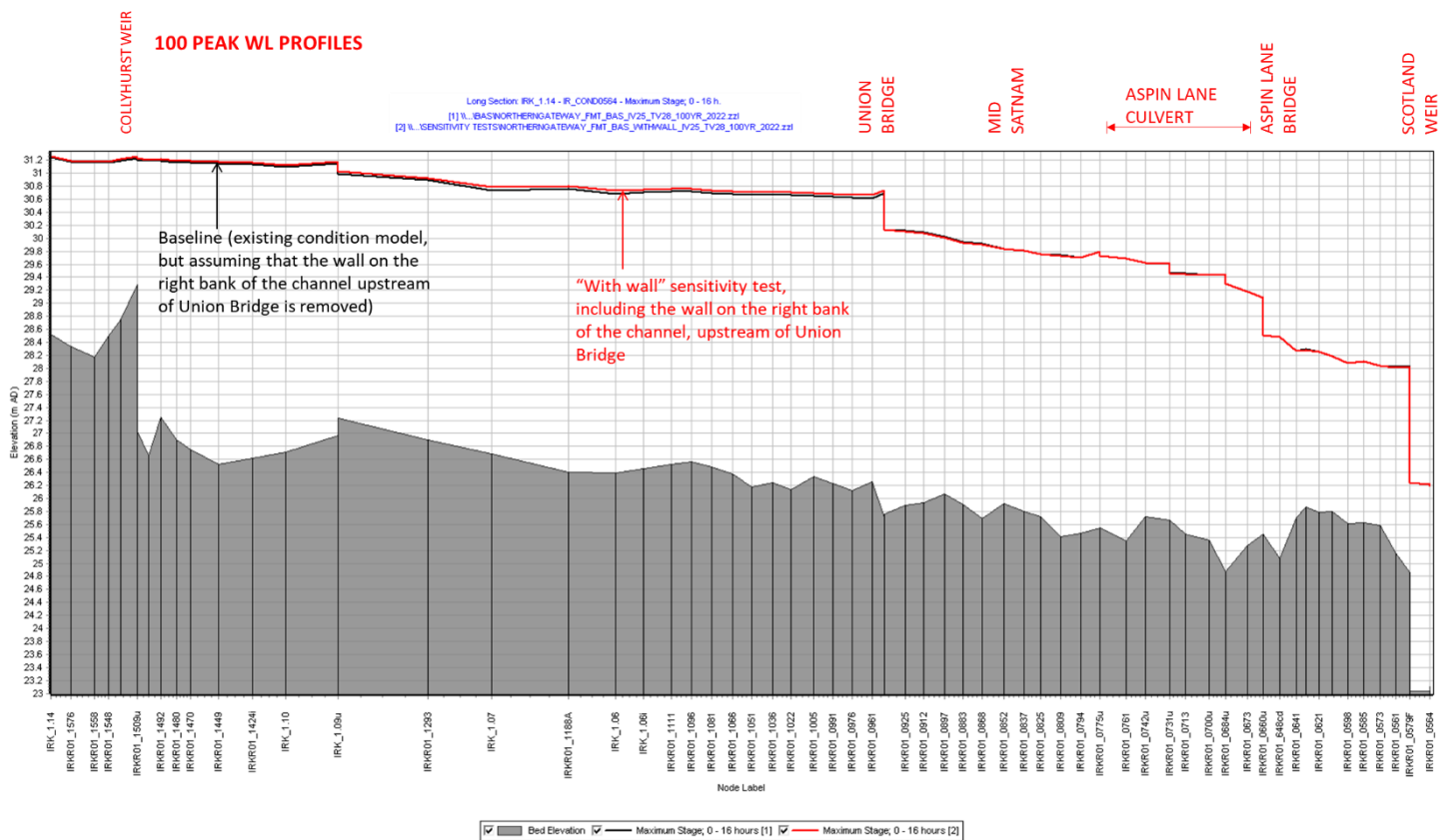


Figure 47: Baseline model 100yr results, compared to results from a sensitivity test without the wall on the right bank of the River Irk upstream of Union Bridge.

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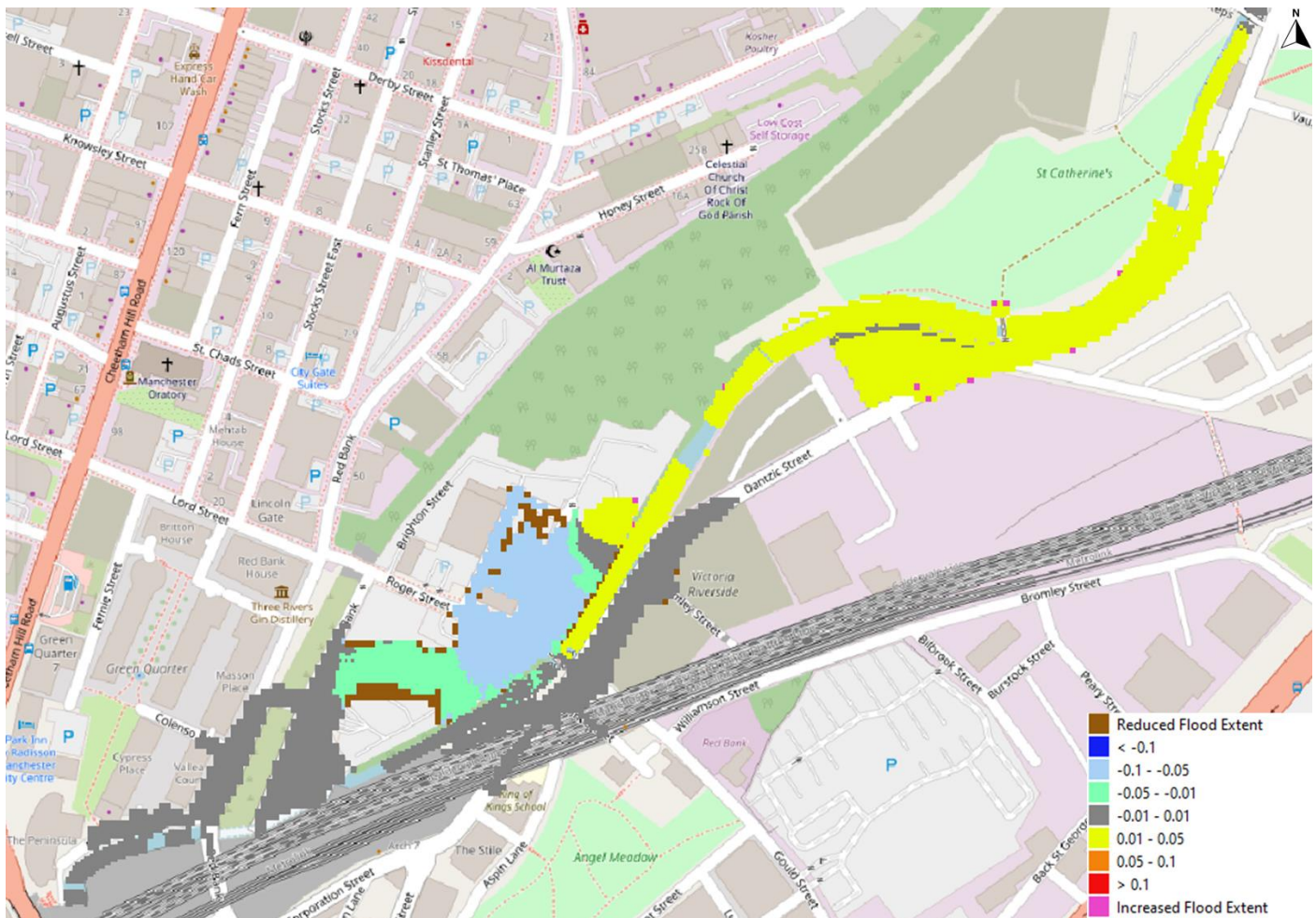


Figure 48: Impact map, showing the difference in 2D flood extent and levels, between the 2022 Baseline model and the sensitivity test in which the wall at Union Plaza is included in the model, run for the 100yr event.

5.1.1 Model Confidence

This hydraulic model aims to provide a best representation of predicted fluvial flooding during a range of rainfall events on the River Irk and Moston Brook. It should be noted that outputs from the model remain estimates of an actual flood event.

The model only represents fluvial flooding from the watercourses and does not include any surface water drainage systems. The model does not take account of antecedent conditions to a rainfall event, nor does it include flooding from other sources such as surface water runoff or groundwater which may exacerbate flooding, depending on the antecedent conditions. The model also assumes that structures are clear of blockages and free flowing; the sensitivity tests outlined above highlight that both Scotland Weir and Aspin Lane Bridge are large hydraulic controls on the River Irk, and so the blockage of these structures is likely to impact water levels along the watercourse.

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The model was found to be particularly sensitive to variations in flow and this should be taken into consideration in any future works planned along the watercourse. The results of sensitivity testing of the model inflows, shown in Figure 42, demonstrate that the model outputs vary by a similar level above and below the outputs of the Baseline model results. A 20% increase in inflows led to, on average, a 0.37m increase in maximum water levels, with a 20% decrease in inflows leading to an average reduction of maximum water levels by 0.58m, therefore giving confidence that flood levels are not particularly sensitive to a change in hydrology. The confidence in the hydrology and Collyhurst Weir is discussed in further detail in the associated hydrology reporting, *VNR-ARP-00-YYY-RP-CH-0001_Flood Estimation Report_200922*.

Whilst the Union Plaza wall has been removed from the Baseline model, several walls considered as defacto defences remain in the model and are assumed as structurally sound in their present condition. It should be noted that defacto defences are not maintained as official flood defences and therefore their failure during an extreme rainfall event cannot be ruled out. It is recommended that if any walls lining the watercourse show deterioration in the future, further sensitivity testing should be undertaken to ascertain the resultant change to flood risk should they fail.

6. 2022 Updated Flood Zone Maps

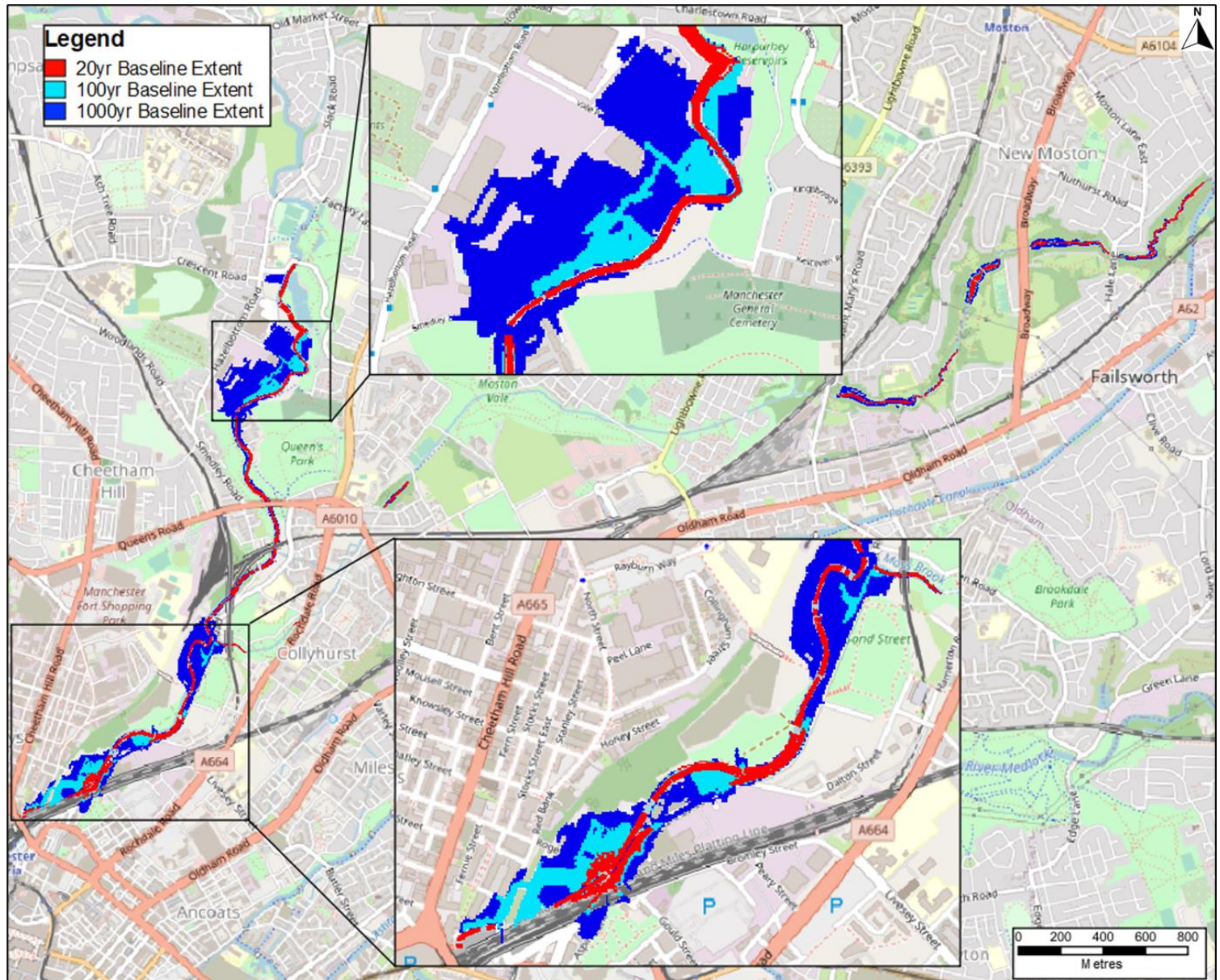
The following, Figure 49, illustrates the updated flood zones map, based on the 2022 Baseline model using the 2022 hydrology, run for the 20yr, 100yr and 1000yr events. Similar to the flood extents presented in Figure 39, the extents presented here have reduced since the Interim 2021 Baseline modelling, primarily as a result of the implementation of the lower flows associated with the 2022 hydrology.

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A.1 Appendix A – Modelled Hydrographs

Figures 50 – 56, below, contains the modelled hydrographs for each hydrology boundary, for each return period modelled, showing the application of the updated hydrology in the model.

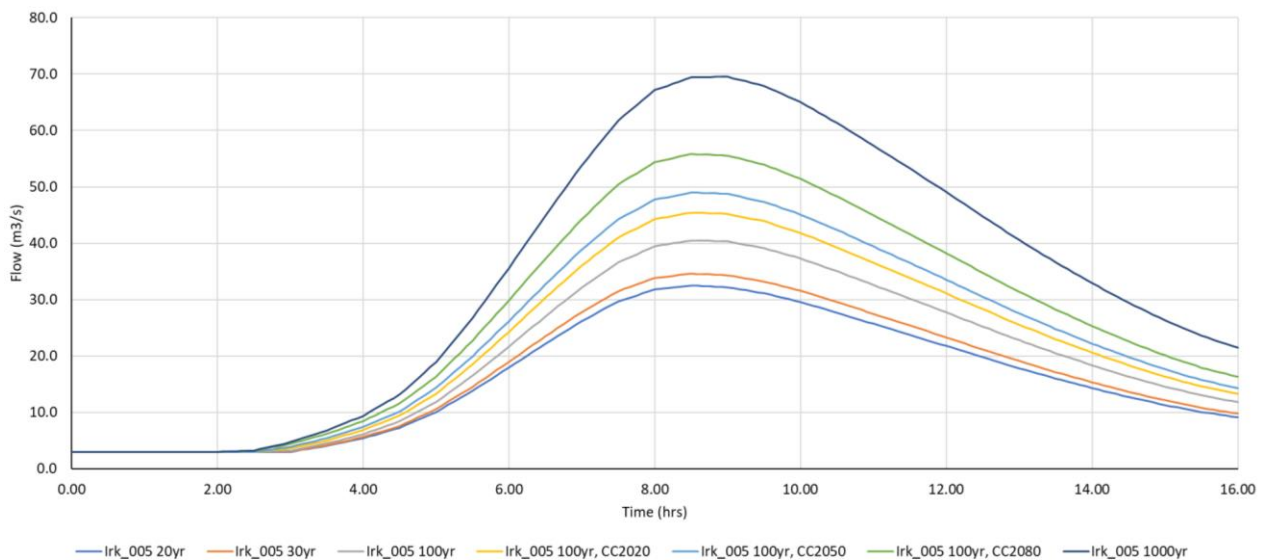


Figure 50: Hydrographs for each modelled return period, at node Irk_005, one of the hydrology inflow boundaries along the River Irk.

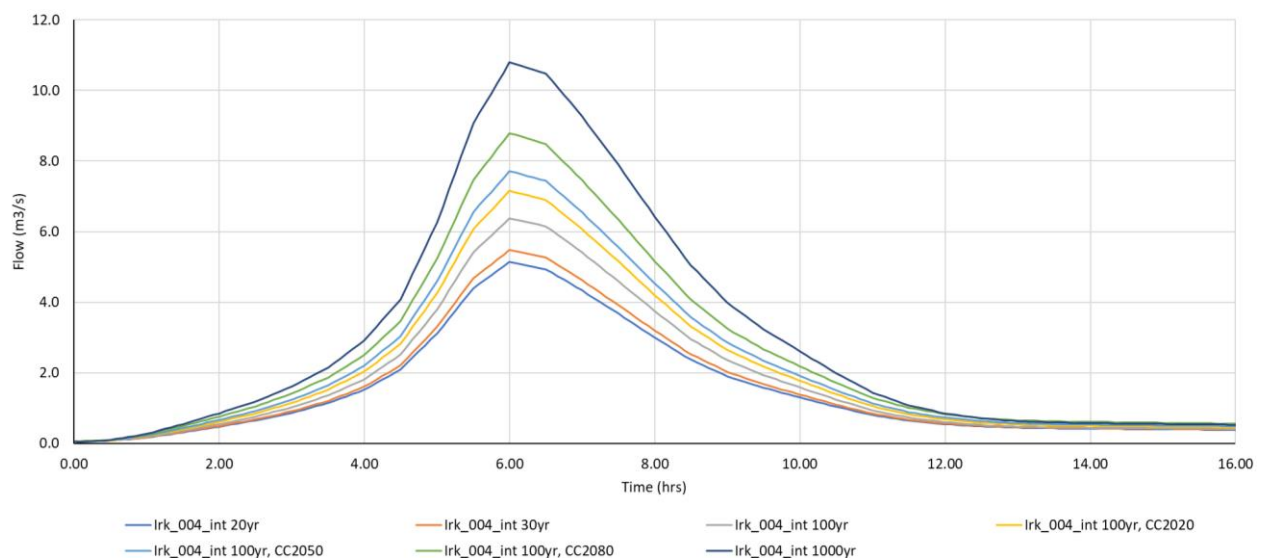


Figure 51: Hydrographs for each modelled return period, at node Irk_004_int, a hydrology inflow boundary along the River Irk.

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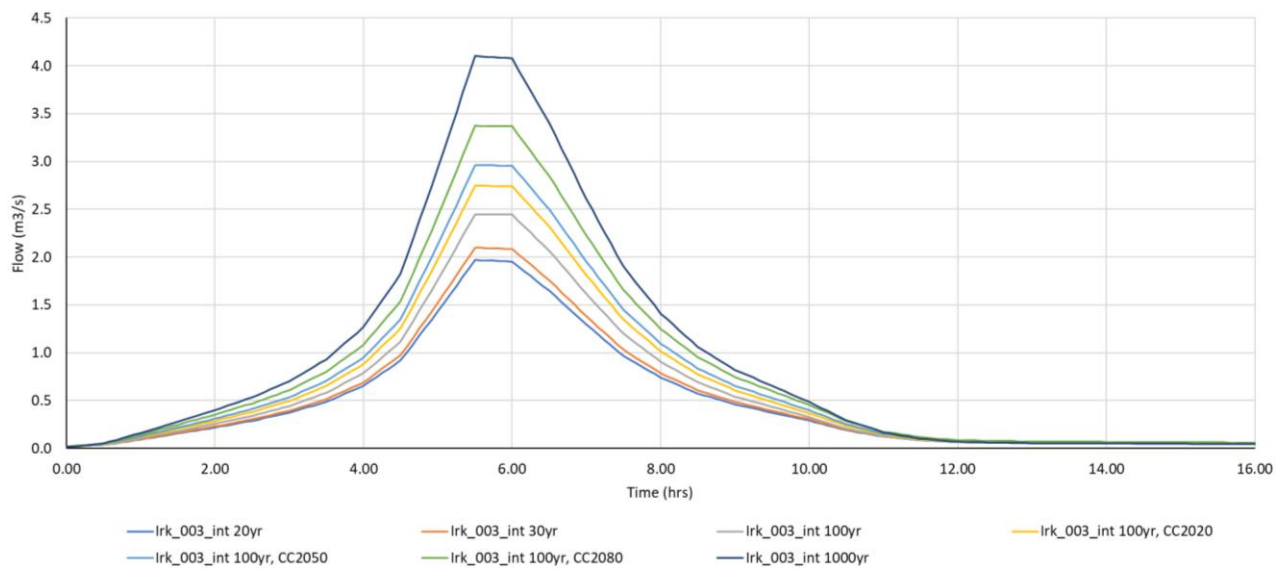


Figure 52: Hydrographs for each modelled return period, at node Irk_003_int, a hydrology inflow boundary along the River Irk.

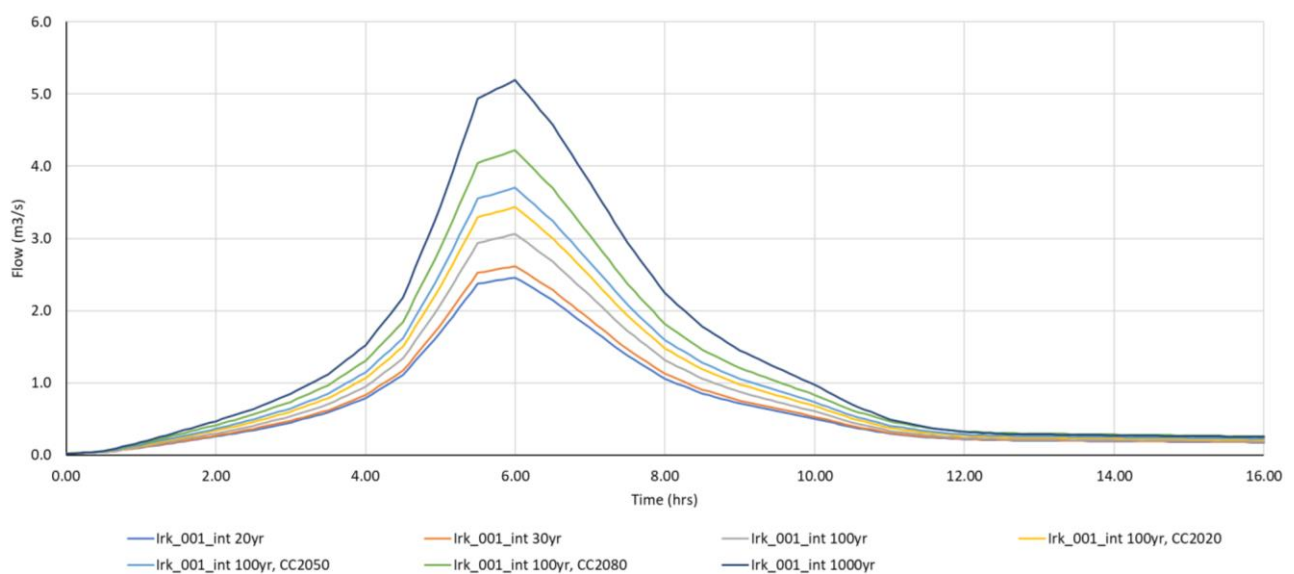


Figure 53: Hydrographs for each modelled return period, at node Irk_001_int, a hydrology inflow boundary along the River Irk.

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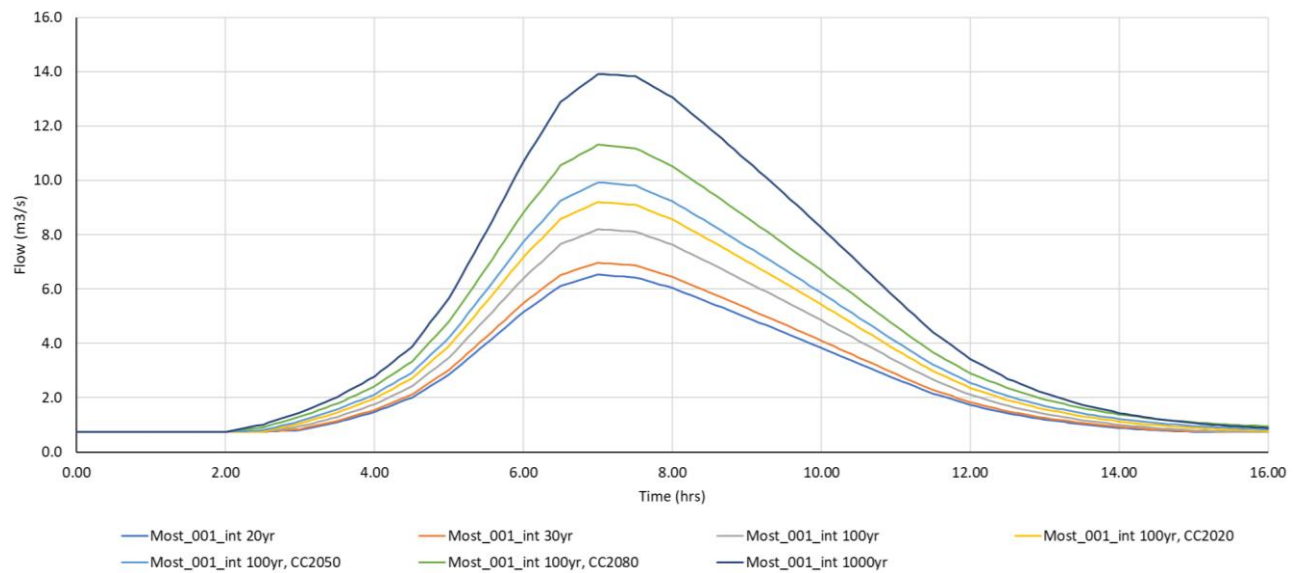


Figure 54: Hydrographs for each modelled return period, at node Most_001_int, a hydrology inflow boundary along the Moston Brook.

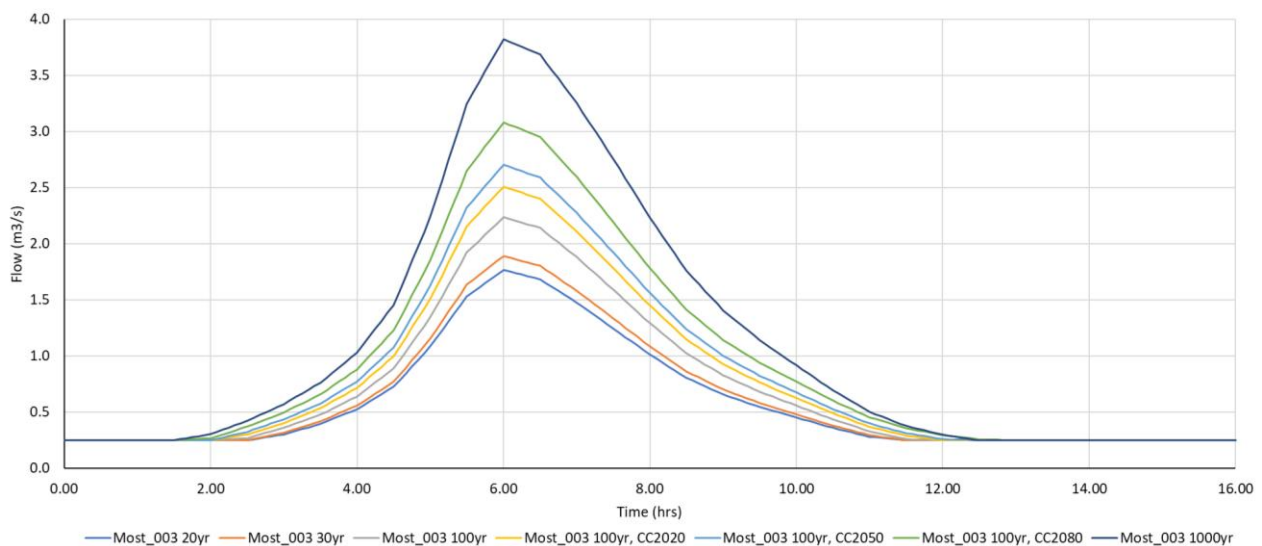


Figure 55: Hydrographs for each modelled return period, at node Most_003, a hydrology inflow boundary along the Moston Brook.

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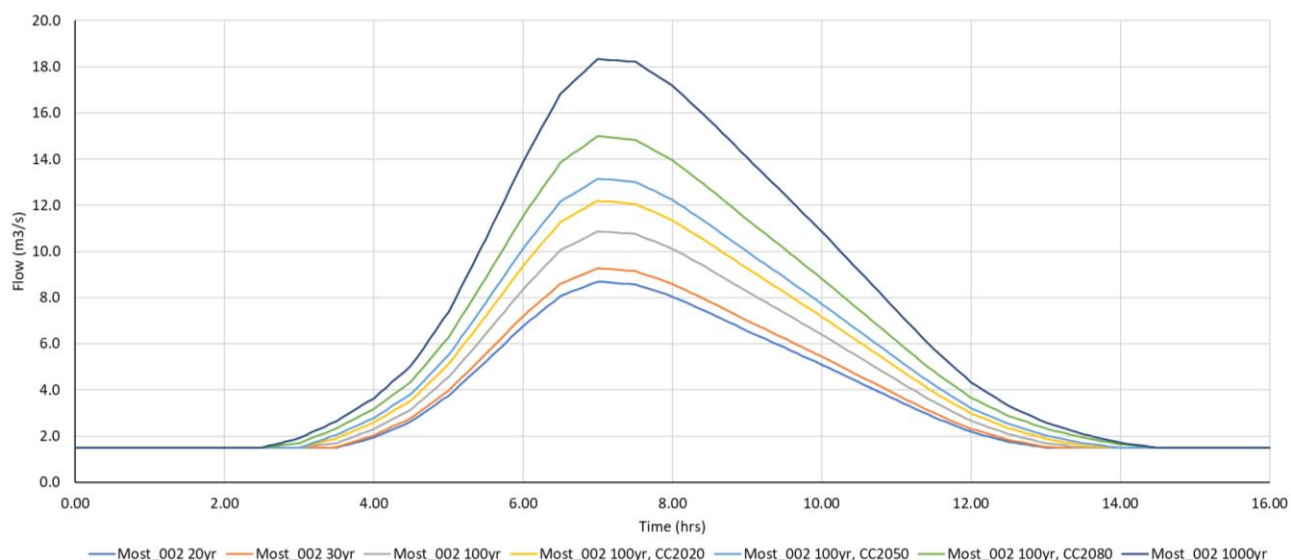


Figure 56: Hydrographs for each modelled return period, at node Most_002, a hydrology inflow boundary along the Moston Brook.

DOCUMENT CHECKING

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Signature			