AtkinsRéalis

# Hydraulic Assessment Report

Mayo County Council

March 2025

# N58 STRADE RIVER BRIDGE REHABILITATION WORKS

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Comhairle Contae Mhaigh Eo
Mayo County Council

OPW Oifig na nOibreacha Poiblí
Office of Public Works

02nd April 2025

OPW Ref: 114-2025

Mr. Mark Gilsenan,
AtkinsRealis,
150 Airside Business Park,
Swords
County Dublin.

Mark.Gilsenan@atkinsrealis.com

**Re: TO315 Mayo Bridges - Strade River Bridge**

**Section 50 Application – Deck replacement of existing structure**

**Strade, Co. Mayo**

Dear Mr. Gilsenan,

I refer to the above Section 50 application received by this office.
The documentation submitted has been examined and based on the Engineers assessment on behalf of the Commissioners of Public Works in Ireland, I confirm the consent of the Commissioners of Public Works under Section 50 of the Arterial Drainage Act, 1945, is granted to the proposed culvert **as follows: TO315 Mayo Bridges**

**Strade River Bridge- Deck replacement of existing structure,Stade, County Mayo.**

AtkinsRéalis were appointed by Mayo County Council for Eirspan Task Order 315 Mayo Bridge Assessments and Strengthening 2023, comprising the assessment and rehabilitation of 10no. bridges in County Mayo. MO-N58-001.00 Strade River Bridge is one of the 7no. structures which required an assessment to be undertaken to confirm the structure's load carrying capacity for HA, HB and SV loading.

The Stage 2 Assessment report for the structure determined a reduced 7.5t load capacity due to bond failure between the concrete and steel beams of the structure with significant delamination and spalling visible to the deck slab soffit providing evidence of the issue. The deck slab was recommended to be either strengthened or replaced with a subsequent structure options report recommending the replacement of the existing deck with a new deck slab while retaining the existing abutments of the structure. The structure is located on the Moy Arterial Catchment Drainage Scheme.

AtkinsRéalis have submitted bridge MO-N58-001.00 for Section 50 consent from the Commissioners of Public Works under Section 50 of the Arterial Drainage Act, 1945. The proposed existing two span structure will be replaced with a single span bridge with a square span of 7.76m and a width of 11.4m. The existing raised concrete apron below the south span is to be lowered to 300mm high. The soffit level of the new structure can only achieve a marginal freeboard of between 10mm and 80mm due to restrictions from existing road levels. The proposed improvements to bridge MO-N58-001.00 improves the overall conveyance capacity of the bridge to meet the 100-year design flood level by removing the central pier and lowering the raised concrete apron.

West Drainage Region recommendation is to approve bridge for Section 50 consent.

<u>Description of structure – MO-N58-001.00</u>

<u>Replacement of existing deck with a clear span of 7.66m and width of 11.4m</u>

| | | | |
|---|---|---|---|
| Upstream & Downstream Invert Level | 15.730 mOD | & | 15.850 mOD |
| Upstream & Downstream Soffit Level | 18.320 mOD | & | 18.320 mOD |
| Upstream & Downstream Design Flood Level | 18.310 mOD | & | 18.240 mOD |

It should be noted that consent is granted only for the purpose of Section 50 and does not absolve the recipient of responsibility for any adverse effects caused by this installation to any third party.

The Commissioners of Public Works are not responsible and accept no liability for any loss or damage whatsoever caused as a result of this development. The Commissioners of Public Works must be informed of any amendments/alterations to the approved application before the works are undertaken.

Signed on behalf of the Commissioners of Public Works in Ireland.

Yours sincerely

Nora Carey

April 2nd 2025

Flood Project Management

AF50 Rev1113

**Construction, Replacement or Alteration of Bridges and Culverts**
**Application for Consent under Section 50 of the Arterial Drainage Act, 1945 & EU (Assessment and Management of Flood Risks) Regulations SI 122 of 2010**

| | | | |
|---|---|---|---|
| Project Name | TO315 Mayo Bridges - Strade River Bridge | Structure Ref No. | MO-N58-001.00 |

| Applicant (Correspondence will issue to agent) | |
|---|---|
| Company or Organisation Name: Mayo County Council | |
| Postal Address: Aras an Chontae, The Mall, Castlebar, Mayo. Ireland , F23 WF90 | |
| Contact Person: Kieran Irwin | |
| Phone: 0872283797 | Fax: |
| E-mail: kirwin@mayococo.ie | |

| Agent (Correspondence will issue to agent) | |
|---|---|
| Company or Organisation Name: AtkinsRéalis | |
| Postal Address: Unit 2B 2200, Cork Airport Business Park , Ireland, T12R279 | |
| Contact Person: Mark Gilsenan | |
| Phone: +353 83 050 9225 | Fax: |
| E-mail: Mark.Gilsenan@atkinsrealis.com | |

| Location and Parameters of crossing | | | |
|---|---|---|---|
| Watercourse: Strade River | | Catchment: | |
| Address (Townland – County): N58 National Secondary Road, Knockshanbally / Strade, Co.Mayo | | | |
| Grid Reference | X: 525753 | Y: 797497 | ITM co-ordinates |
| Hydrometric Station(s) utilized (including reference number): | N/A | | |
| Area of Contributing Catchment: | 22.46 Km$^2$ | Road Reference: N58 National Secondary Road, Knockshanbally / Strade, C | |
| Design Flood Flow: | 36.043 m$^3$/s | Annual Exceedance Probability (AEP): 1% ( + CC 20%)% | |

| Statement of Authenticity | |
|---|---|
| I hereby certify that the information contained in this application form, along with all appended supporting information, has been checked by me and that all statements are true and accurate. | |
| Name: | Mark Gilsenan |
| Company/Organisation: | AtkinsRéalis |
| Signature: | [signature] |
| Date: | 26/03/2025 |

| Application Check List | |
|---|---|
| COMPLETED APPLICATION FORM | X |
| SUPPORTING HYDROLOGICAL AND HYDRAULIC INFORMATION | X |
| PHOTOGRAPHS COVERING SITE OF ALL PROPOSED WORKS | X |
| SCALED PLAN OF BRIDGE/CULVERT/APPROACH EARTHWORKS | X |
| SCALED CROSS SECTION OF BRIDGE/CULVERT/APPROACH EARTHWORKS | X |
| SCALED LONG SECTION OF CHANNEL THROUGH BRIDGE/CULVERT | X |
| DETAILS OF RELEVANT EXISTING STRUCTURES | X |
| COMPLETED STATEMENT OF AUTHENTICITY | X |
| PLAN OF CATCHMENT AREA | X |
| COPY OF NOTICE OF GRANT OF PLANNING PERMISSION WITH CONDITIONS *1 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *For OPW use only* | *Date of Receipt* | | | | | | | |
| *OPW Drainage Maintenance Region* | *East* | ☐ | *South East* | ☐ | *South West* | ☐ | *West* | ☐ |

If the application form is not completed correctly, and in its entirety, the application may be deemed invalid and returned for correction.

| *Correspondence Number* | *OPW Register No:* | |
|---|---|---|
| | *Consent Issued* | ☐ |

## ADDITIONAL INFORMATION

### Hydrological Analysis

| Methodology Applied | | |
|---|---|---|
| Method Used | Tick box if used or state other | Flow *2 ($m^3$/sec) |
| 6 – Variable Catchment characteristics | | |
| 3 – Variable Catchment Characteistics | | |
| IH 124 | ☐ | |
| Gauged Flow | ☐ | |
| Unit Hydrograph | ☐ | |
| Other | ☐ | |
| Other | ☐ | |
| FSR ☐ | FSU ☒ | Other ☐ |
| Comments | small catchment equation 11.258 m3/s<br>FSU no Pivotal site 6.727 m3/s<br>FSU single Pivotal site 7.973 m3/s<br>FSU 3 Pivotal SIte 9.712 m3/s (selected) | |

| Factors Applied | |
|---|---|
| Type of Factor | Value Used |
| Climate Change | 20% |
| Irish Growth Curve | |
| Factor for Standard Error | |
| Drained Channel | |
| Other | |
| Growth Fact Q100 | 3.093 |
| | |
| Tidal ☐ | |
| Comments<br>Not affected by Tidal | |

### Hydraulic/Structure Details

| | |
|---|---|
| Description of Structure*3 Existing 2 span structure to be replaced with a single span bridge with a square span of 7.76m and a width of 11.4m. The existing raised concrete apron below the south span is to be lowered to 300mm high. | |
| Effective Conveyance Area *4 17.92 m2 $m^2$ | |
| Upstream Invert Level 15.73 mOD | Downstream Invert Level 15.85 mOD |
| Upstream Soffit Level 18.32 mOD | Downstream Soffit Level 18.32 mOD |
| Upstream Design Flood Level 18.31 mOD | Downstream Design Flood Level 18.24 mOD |

NOTES :

1. In line with OPW policy, section 50 approvals should be sought for bridges and culverts that are necessary for access or deemed acceptable by the planning authority. A copy of the notice of grant of planning permission with all conditions should be enclosed with all applications, that are not exempt development under the Planning and Development Act, 2000, as evidence that these factors have been considered.
2. Flow is the estimated flow from the catchment, without any factors applied.
3. The following details are to be included: the channel bed level, invert and soffit levels of the structure along with the width, length and total conveyance area. Any environmental considerations such as bed depression, baffles, mammal walkways etc. should be described.
4. Effective conveyance area is from channel bed level to design flood level.
5. All levels must be given to Ordnance Datum, Malin Head.

If the application form is not completed correctly, and in its entirety, the application may be deemed invalid and returned for correction.

AtkinsRéalis

## Strade River Bridge Hydraulic Assessment

Mayo County Council

March 2025

# TASK ORDER NO.315 MAYO BRIDGE ASSESSMENTS & STRENGTHENING 2023

# Notice

This document and its contents have been prepared and are intended solely as information for Mayo County Council and use in relation to Task Order No.315 Mayo Bridge Assessments & Strengthening 2023

AtkinsRéalis Ireland Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

## Document history

Document title: Strade River Bridge Hydraulic Assessment

Document reference: 0088572DG0050

| Revision | Purpose description | Originated | Checked | Reviewed | Authorised | Date |
|---|---|---|---|---|---|---|
| 0.0 | Draft for Information | YS | MG | MJ | MJ | 21/02/2025 |
| 1.0 | Final Issue | YS | MG | MJ | MJ | 26/03/2025 |
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## Client signoff

| | |
|---|---|
| **Client** | Mayo County Council |
| **Project** | TASK ORDER NO.315 MAYO BRIDGE ASSESSMENTS & STRENGTHENING 2023 |
| **Job number** | 0088572 |
| **Client signature/date** | |

# Contents



## Tables

## Figures

# 1. Introduction

AtkinsRéalis were appointed by Mayo County Council for Eirspan Task Order 315 Mayo Bridge Assessments and Strengthening 2023, comprising the assessment and rehabilitation of 10no. bridges in County Mayo. MO-N58-001.00 Strade River Bridge is one of the 7no. structures which required an assessment to be undertaken to confirm the structure's load carrying capacity for HA, HB and SV loading.

The Stage 2 Assessment report for the structure determined a reduced 7.5t load capacity due to bond failure between the concrete and steel beams of the structure with significant delamination and spalling visible to the deck slab soffit providing evidence of the issue. The deck slab was recommended to be either strengthened or replaced with a subsequent structure options report recommending the replacement of the existing deck with a new deck slab while retaining the existing abutments of the structure.

An Arterial Drainage Act (1945) - Section 50 application was deemed required for the deck replacement works with this Hydraulic Assessment Report supporting the Section 50 Application.

# 2. Site Location

MO-N58-001.00 Strade River Bridge carries the N58 National Secondary Road over the Strade River in Strade, Co. Mayo.

The ITM co-ordinates of the existing structure are:
Easting: 525753 Northing: 797497

The location of the existing structure is shown in Figure 2-1 overleaf.

Upstream of the site location has a history of flooding with the medium probability flood extent mapping for the site location shown in Figure 2-2 overleaf. The most recent flood event in November 2024 caused flooding to the properties located south of the bridge and the church hall and car park to east.

A protected masonry arch bridge is located 40m upstream of the bridge and forms the primary constraint to the flow at the site location with the masonry arch bridge reported to be flowing at full capacity at the time of the November flood event. The arch bridge has spans of 2.25m, 2.95m and 2.25m separated by 2no. 1.3m wide masonry piers. Raised concrete aprons were previously installed in the outer spans measuring 650mm above the bed level of the central span.

From review of the structure cross sections the upstream masonry arch bridge is considered to be causing a choke on the flow upstream of Strade River Bridge which attributes to the repeated flood events that occur at the location. See Figure 2-3 overleaf for the downstream elevation of the masonry arch bridge.

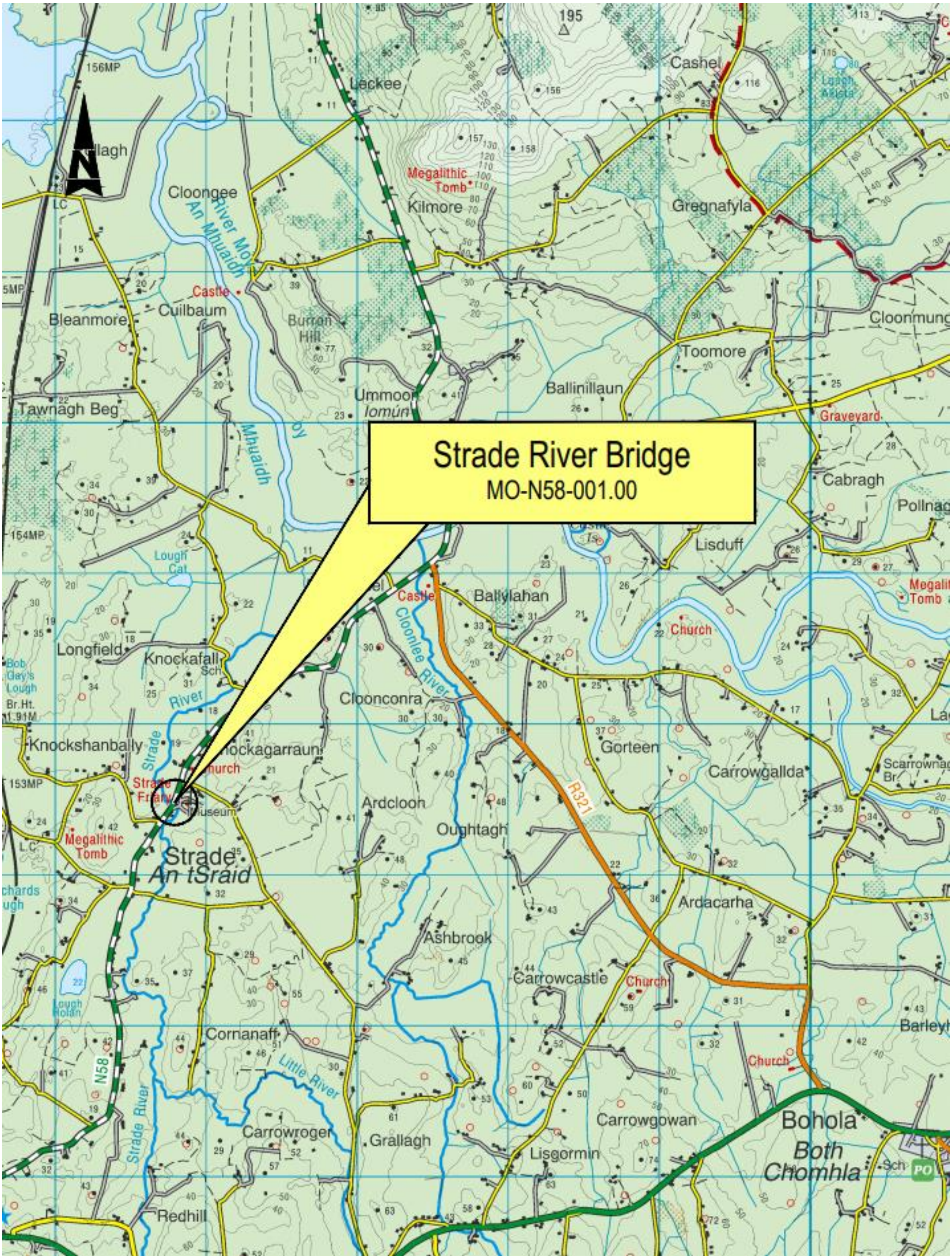



Figure 2-1 - Structure Location Map


**Figure 2-2 – Medium Probability Flood Extent Mapping**

**Figure 2-3 – Downstream elevation of masonry arch bridge located 40m upstream of structure**

# 3. Existing Structure

The existing bridge comprises a two span filler beam deck bridge with the filler beam deck slab comprising railway girders encased in concrete and supported on mass concrete pier and abutments.

The structure has square spans of 3.44m and 3.42m and skew spans of 3.82m and 3.79m for the south and north spans respectively. The overall square length of the structure is 7.76m with a skew length of 8.6m. The structure has a skew of 26 degrees.

The overall kerb-to-kerb width on the bridge is 6.90m with the carriageway measuring 5.70m wide. Concrete verges are provided across the structure measuring 1.1m (east) and 1.7m (west) wide respectively with concrete parapets also provided measuring 900mm and 750mm high respectively. The overall width out-to-out on the structure is 10.3m square to the carriageway with a skewed width of 11.4m.

A low flow channel is provided through the north span of the structure with a raised concrete apron provided in the south span of the bridge, with a c.700mm difference in bed level between the 2no. spans.

See Figures 3-1 and 3-2 below for the bridge elevations.

**Figure 3-1 – View of the west (downstream) elevation**

**Figure 3-2 – View of the east (upstream) elevation**

# 4. Proposed Works

The proposed works to the existing Strade River Bridge are outlined below.

The existing bridge superstructure is proposed to be demolished with a new single span replacement deck constructed to align with the retained substructure. The proposed replacement deck is to be formed of precast prestressed concrete beams with an insitu concrete deck infill.

New independent foundation supports would be located behind the existing abutment walls with the proposed foundations comprising reinforced concrete bored cast in place piles and pilecaps. The existing pier and concrete apron are to be demolished to improve conveyance through the structure with a new reduced height (300mm) concrete apron constructed to maintain the existing low flow channel following consultation with IFI.

The existing carriageway width is to be retained across the new superstructure with the east raised verge width increased to achieve a minimum width of 1.5m. New 1.25m high reinforced concrete masonry clad parapets would be constructed over the length of the structure with safety barriers installed on both verges approaching and crossing the bridge.

# 5. Design Parameters

The following parameters were identified for this study in accordance with OPW requirements.

1. A bridge must be capable of passing a fluvial flood flow with a 1% annual exceedance probability (AEP) or 1 in 100-year flow without significantly changing the hydraulic characteristics of the watercourse.
2. Flow estimates were subject to a 1.2 factor to account for climate change.
3. A bridge must be capable of operating under the above design conditions while maintaining a freeboard of at least 300mm.
4. If the land potentially affected includes dwellings and infrastructure, it must be demonstrated that Those dwellings and/or infrastructure will not be adversely affected by the bridge's construction.

# 6. Catchment Description

## 6.1 Introduction

The FSU Web Portal is not available during this study period due to its ongoing upgrade. As a result, the OPW's Flood Frequency and Hydrograph Spreadsheet (October 2024) is being used to determine the design flow in this case. This spreadsheet acts as an alternative tool to calculate the necessary flow values for flood analysis and hydraulic design, ensuring that the required information is available despite the unavailability of the portal.

## 6.2 Catchment Site Selection

### 6.2.1 Selection of the Subject site

The catchment is associated with a contributing gauge or river node, and it is important to identify the most suitable node ID. Based on the proximity to the bridge location, the nearest node ID, 34_3826_6, has been selected.

Based on the selected node ID, the following physical catchment parameters are selected.

**Table 6-1 - Catchment Parameters**

| **Physical Catchment Descriptors** | | | |
|---|---|---|---|
| AREA | 22.46 | Node East | 125725 |
| BFIsoils | 0.47 | Node North | 297494 |
| SAAR | 1184.54 | Centroid East | 127520 |
| FARL | 1.00 | Centroid North | 292130 |
| DRAIND | 1.83 | ALLUV | 0.00 |
| S1085 | 7.83 | ARTDRAIN | 0.00 |
| ARTDRAIN2 | 0.27 | FOREST | 0.00 |
| URBEXT | 0.00 | | |


**Figure 6-1 - The ungauged node near to the bridge**

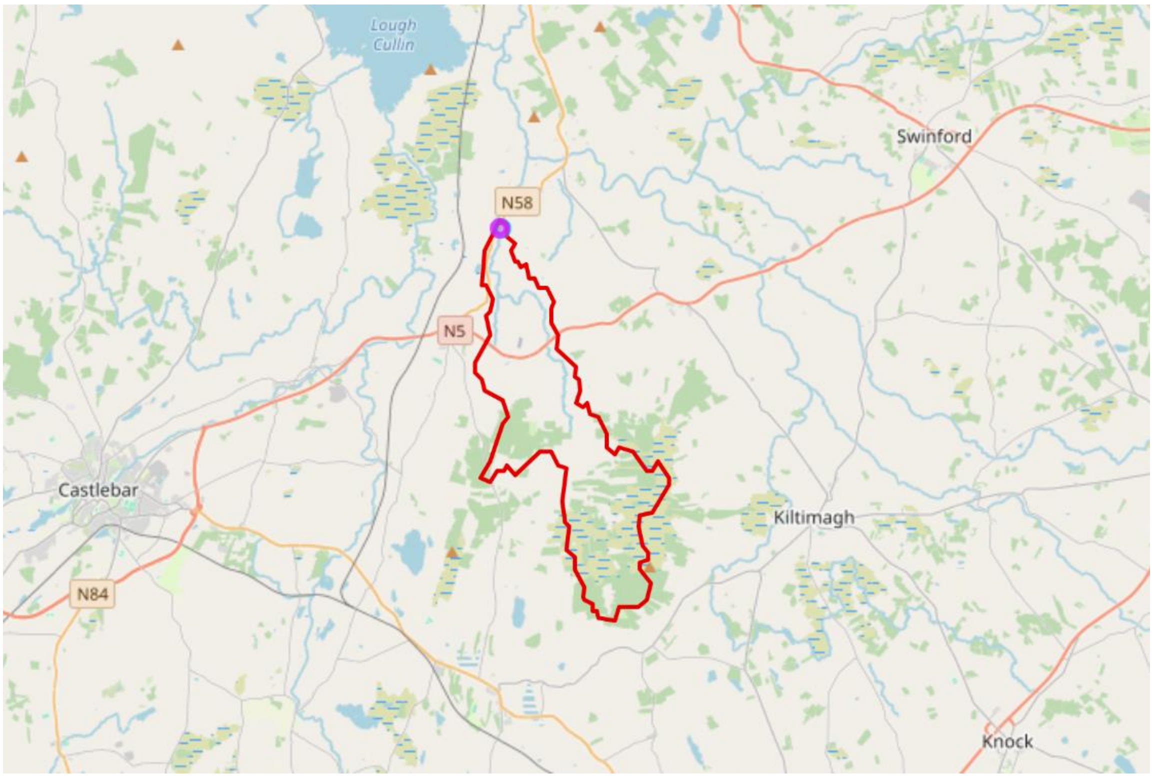



**Figure 6-2 - Catchment Area**

## 6.3 Flow Assessment

The OPW Flood Estimation Spreadsheet uses the index flood, defined as the median annual maximum ($Q_{MED}$), as a standardised metric for flood analysis. $Q_{MED}$ represents the median of the annual maximum (AM) flow series, meaning that 50% of AM flows are higher than $Q_{MED}$ and 50% are lower. This equates to an annual exceedance probability (AEP) of 0.5, corresponding to a return period of two years on the AM frequency scale.

$Q_{MED}$ estimation is robust even when flood rating curves are not entirely accurate, making it a reliable parameter for flood frequency analysis across various hydrological conditions

The spreadsheet provides four methods for estimating the median annual flood ($Q_{MED}$) to assist in flood frequency analysis. These methods are outlined as follows:

1. Estimation of $Q_{MED}$ without the use of a small catchment less than 25 sq.km
2. Estimation of $Q_{MED}$ without the use of a pivotal site
3. Estimation of $Q_{MED}$ by using one pivotal site
4. Estimation of $Q_{MED}$ by using three pivotal sites

### 6.3.1 Estimation of $Q_{MED}$ for a small catchment less than 25 sq.km

Under the Flood Study Update (FSU), new regression equations for small catchments have been derived as part of the evaluation of various small catchment flood estimation techniques. These new equations were developed using five variables, identified as Physical Catchment Descriptors (PCDs): AREA (catchment area), SAAR (standard average annual rainfall), BFI (base flow index), FARL (flood attenuation by reservoirs and lakes), and S1085 (slope of the main river).

$$Q_{MED} = 2.3848*10^{-5}AREA^{0.9245}SAAR^{1.2695}BFI^{-.9030}FARL^{2.3163}S1085^{0.2513}$$

### 6.3.2 Estimation without the use of a pivotal site

$Q_{MED}$ is calculated using the 7-Variable equation that has been calibrated to the network of gauging stations used in the FSU research. These stations possess data up to and including the hydrometric year 2002. The 7 variable equation is as follows:

$$Qmed = 3.117 \times 10^{-6} \times AREA^{1.07} \times BFIsoils^{-1.342} \times SAAR^{1.306} \times FARL^{2.217} \times DRAIND^{0.341} \times S1085^{0.185} \times (1 + ARTDRAIN2)^{0.408}$$

An adjustment for urbanisation is also included where the urban adjustment is calculated as: $(1 + URBEXT)^{2.9}$

### 6.3.3 Estimation of $Q_{MED}$ by using one pivotal site

This method uses a **pivotal site** (a site with similar hydrological characteristics to the site of interest) to aid in estimating $Q_{MED}$. A pivotal site can be one with a good flow record that is hydrologically similar to the site in question.

### 6.3.4 Estimation of $Q_{MED}$ by using three pivotal sites

This method extends the concept of the pivotal site by using three pivotal sites to improve the robustness of the $Q_{MED}$ estimate.

### 6.3.5 $Q_{MED}$ selection

Based on the three methods outlined above for estimating $Q_{MED}$, the following $Q_{MED}$ values have been derived. .

| | | |
|---|---|---|
| a. | Using the small catchment equation | 11.258 $m^3/s$ |
| b. | Using no Pivotal Site | 6.727 $m^3/s$ |
| c. | Using 1 Pivotal Site (30002) | 7.973 $m^3/s$ |
| d. | Using 3 Pivotal Sites (25034, 14104, 26022) | 9.712 $m^3/s$ |

Based on the analysis of various $Q_{MED}$ values and historical data, the recommended $Q_{MED}$ value for this project is 9.712 m³/s, derived using three pivotal sites (25034, 14104, 26022). This value was selected because it incorporates multiple data points, providing a more comprehensive and reliable estimate of the median annual flood. Additionally, historical data from the OPW National Indicative Fluvial Map (NIFM) for a 1% Annual Exceedance Probability (AEP) shown in Figure 2-2 above indicates that the bridge location is not affected by such flood events, confirming that the higher $Q_{MED}$ value from the Small Catchment equation (11.258 m³/s) likely overestimates the flood risk. Therefore, the $Q_{MED}$ value of 9.712 m³/s offers a balanced approach, aligning well with historical observations while ensuring a conservative and accurate flood risk assessment for the bridge.

## 6.4 Return Period

According to the OPW guidelines for the hydraulic design of bridge structures, any proposed bridge design must be designed to accommodate a fluvial flood flow with a 1% annual exceedance probability (AEP) (equivalent to a 1 in 100-year flood event) without causing significant changes to the hydraulic characteristics of the watercourse.

This ensures that the bridge does not adversely impact the watercourse's flow regime, stability, or flood risk in the surrounding area. Compliance with this standard is critical for safeguarding both the bridge and the environment during extreme flood events.

## 6.5 Determination of $Q_T$

The $Q_T$ is the T-year return period flood, representing the flood peak with an annual exceedance probability (AEP) of 1/T. This means that a flood of this magnitude or greater has a 1/T probability of occurring in any given year.

The estimation of $Q_T$ is essential in various practical scenarios, ranging from gauged sites (with observed flow data) to ungauged sites (without direct flow records), and for both short and long periods of data availability.

The index flood method is recommended for estimating $Q_T$. In this method, $Q_T$ is calculated as:

$$Q_T = Q_{MED} \times x_T$$

Where:

$Q_{MED}$: The median annual maximum flow (index flood), representing the 2-year return period flood.

$x_T$: The growth factor, which scales $Q_{MED}$ to represent the desired return period T.

This approach is versatile and widely used due to its ability to handle a range of hydrological conditions and data limitations.

In regional flood frequency analysis, $D_{ij}$ plays a crucial role in determining $x_T$, the flood peak for a given return period T. The $D_{ij}$ value in flood assessment typically represents a dissimilarity or distance metric between two sites i and j. This allows for the transfer of statistical information, such as growth factors or flood frequency curves, from gauged sites to ungauged sites. The ability to quantify how similar or dissimilar two sites are through Dij reduces uncertainty in flood prediction models, particularly in regions where direct data collection is not feasible.

The L-moment ratio diagram in the spreadsheet is a graphical tool used in hydrology, particularly in flood frequency analysis, to summarize the relationships between the L-moments of different probability distributions. L-moments are statistical measures derived from the order statistics of a dataset, and they are used to describe the shape of the probability distribution of hydrological variables, such as streamflow or rainfall.

**Table 6-2 - Final Growth Factors and Design Flows**

| Return Period (T) | Growth Factors | Design Flows |
|---|---|---|
| 1.3 | 0.630 | 6.115 |
| 2 | 1.000 | 9.712 |
| 5 | 1.560 | 15.153 |
| 10 | 1.931 | 18.755 |
| 20 | 2.287 | 22.211 |
| 25 | 2.400 | 23.307 |
| 30 | 2.492 | 24.199 |
| 35 | 2.569 | 24.951 |
| 50 | 2.748 | 26.684 |
| 100 | 3.093 | 30.036 |
| 200 | 3.437 | 33.375 |
| 500 | 3.890 | 37.781 |
| 1000 | 4.233 | 41.111 |

Thus, $Q_{100}$ is selected as 30.036 m³/s.

## 6.6 Climate Change Considerations

The Flood Policy Review Report (2004) produced by OPW states that climate change considerations should be taken into consideration when undertaking flood risk assessments. Two possible scenarios are proposed in this report:

- The ‘Mid-Range Future Scenario’ (MRFS) considers the more likely estimates of climate change to the future scenario drivers by 2100. This includes extreme rainfall depths increase by 20%, a resulting 20% increase in flood flow, 0.500 m sea level rise and decrease in time to peak by 1/6 (Tp) due to deforestation. This is supported by the Defra FCDPAG3 (2006) guidance policy, where 20% is used as a sensitivity range to be adopted for peak river flow.

- The ‘High End Future Scenario’ (HEFS) considers the less likely estimates of climate change to the future scenario drivers by 2100. This includes extreme rainfall depths increase by 30%, a resulting 30% increase in flood flow, 1 m sea level rise and decrease in time to peak by 1/3 (Tp) and addition of 10% to the Standard Percentage Runoff (SPR) rate due to deforestation.

In this study, the MRFS is considered, and the Q100CC (100-year flood flow under climate change conditions) is 36.043 m³/s. This value represents the estimated flow rate for a 100-year flood event, accounting for the potential effects of climate change on the river system.

| | |
|---|---|
| $Q_{100}$ | 30.036 m³/s. |
| $Q_{100CC}$ | 36.043 m³/s |

# 7. Hydraulic Model

## 7.1 Introduction

Various methods are available for the hydraulic design of bridges, each suited to different levels of complexity and analysis requirements. One-dimensional modelling focuses on flow changes along a single direction (x-axis) and is efficient for simpler scenarios. Two-dimensional modelling accounts for flow variations in two directions (x and y), computing horizontal velocity either as components ($V_x$, $V_{\backslash ZA\backslash}$) or as a vector, making it suitable for more complex flow patterns such as meandering rivers or floodplains. Three-dimensional modelling, or Computational Fluid Dynamics (CFD), captures flow variations in three directions (x, y, and z) and is ideal for highly detailed analyses involving turbulence and intricate flow around structures. Lastly, physical modelling involves scaled physical representations of bridges or components, offering an intuitive and practical way to validate computational models and understand flow behaviour in specific scenarios, such as around piers or abutments. The selection of the appropriate method depends on site conditions, design requirements, and the desired detail level.

The method used in this study is widely recognised and commonly adopted, originating from the United States Bureau of Public Roads (1970) and more recently by the Federal Highway Administration (FHWA) is referred to as the HDS-1 method. It is based on findings from hydraulic model studies and field measurements conducted during actual floods.

Key considerations of this method include:

- Flow Types: The method differentiates between subcritical and supercritical flow regimes, addressing scenarios such as flow contraction and expansion.
- Bridge Geometry: Parameters such as the size and shape of the opening, pier configurations, skew angles, and bridge alignment relative to the channel are evaluated.
- Hydraulic Losses: It accounts for energy losses due to friction, turbulence, and pier-induced disturbances, using coefficients to estimate these effects.
- Backwater Prediction: By combining hydraulic principles with empirical coefficients derived from studies, the method calculates the backwater height for a given flow rate and channel geometry.

**Type I Flow**

Both the normal flow depth and the constricted flow depth are above the critical depth throughout the channel. This can be identified as subcritical flow, the most widely encountered flow at the bridge openings, in practice.

There are two variations of the Type II flow which will be described here as Type IIA and Type IIB.

**Type IIA Flow**

The normal flow depth is subcritical. The constricted flow passes through the critical depth within the constricted section but emerges from the constriction above the channel's critical depth. The flow is supercritical through the constriction but becomes subcritical downstream of the bridge.

**Type IIB Flow**

Similar to Type IIA flow, except that the flow emerges from the constriction at a depth less than the channel's critical depth.

The water surface for Type IIB flow starts above the normal water surface and critical depth upstream passes through critical depth in the constriction, next dips below critical depth downstream from the constriction and then returns to normal depth. The return to normal depth can be rather abrupt, taking place in the form of a poor hydraulic jump since the normal water surface in the stream is above critical depth.

**Type III Flow**

The normal water surface and the water surface through the constriction are below the critical depth. The flow is therefore supercritical throughout. Theoretically, backwater should not occur for this type since the flow is supercritical.

**Type IV Flow**

The normal flow is supercritical, but the constriction is sufficient to force a hydraulic jump upstream of the bridge. As a result, the flow immediately upstream of the bridge is subcritical, becoming supercritical through the constriction and continuing supercritical downstream.

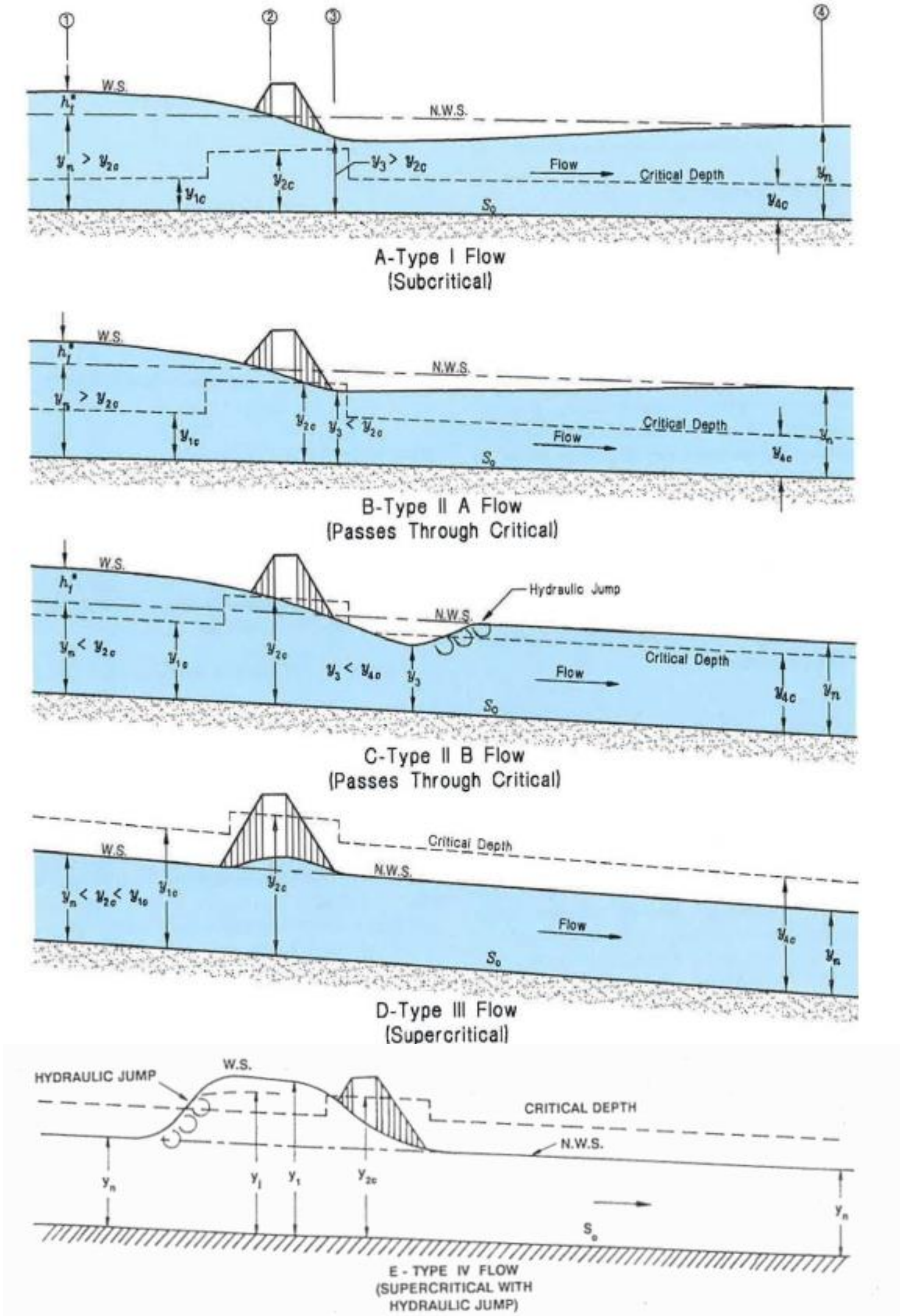



**Figure 7-1 - Types of Flow**

This classification helps in understanding and analysing the hydraulic behaviour of the flow under various conditions, ensuring accurate design and assessment of the bridge structure.

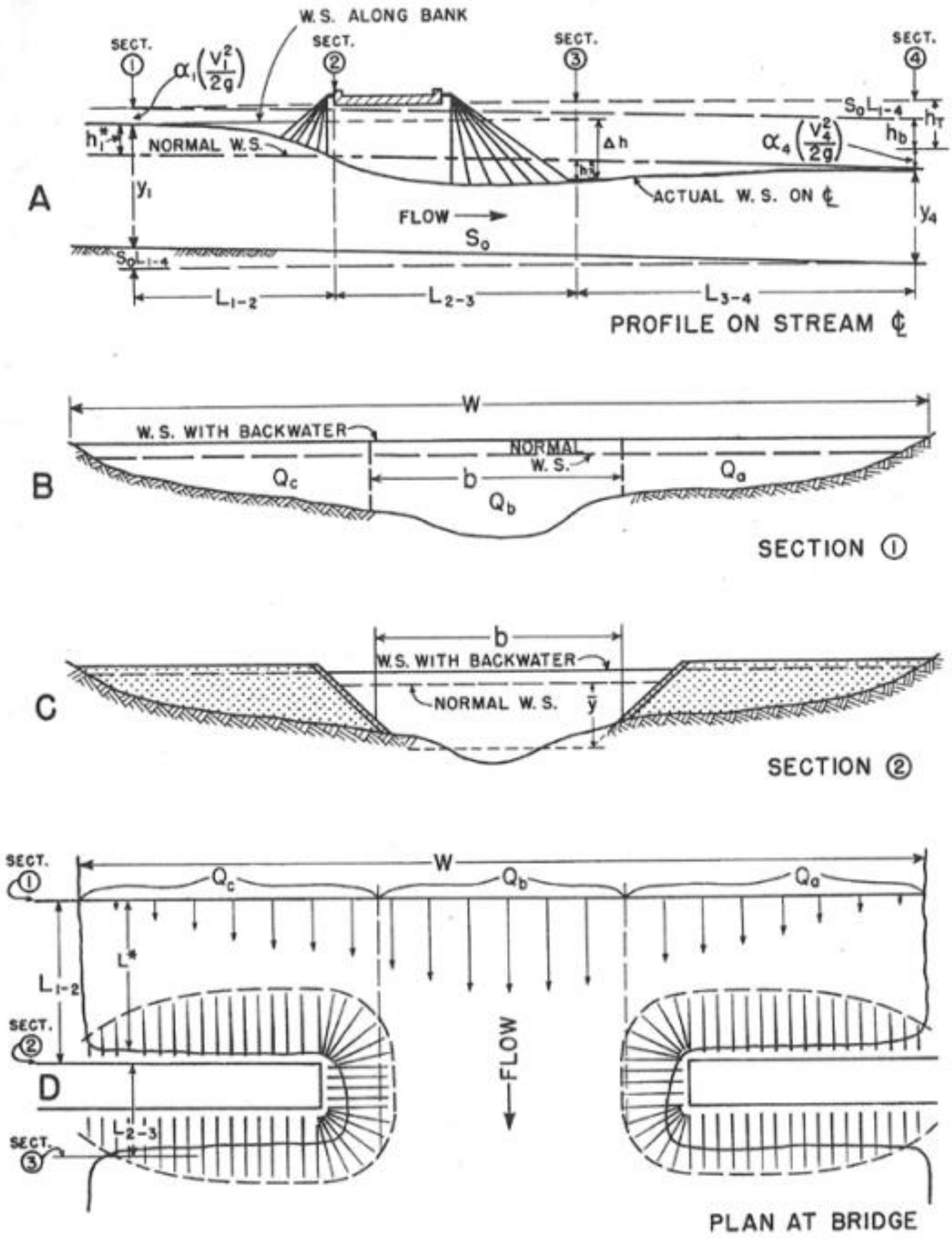



**Figure 7-2 - The cross sections defined for the assessment of flow**

The expression for backwater has been derived by applying the principle of energy conservation between two critical points: the point of maximum backwater upstream of the bridge and the point downstream where the normal stage has been re-established. This approach ensures that the changes in flow energy caused by the bridge's constriction and flow conditions are accurately accounted for in the hydraulic analysis.

$$h_1^* = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[ \left( \frac{A_{n2}}{A_4} \right)^2 - \left( \frac{A_{n2}}{A_1} \right)^2 \right] \frac{V_{n2}^2}{2g} \quad (6)$$

where

$h_1^*$ = total backwater (m)

$K^*$ = total backwater coefficient

$\alpha_1$ and $\alpha_2$ = Kinetic energy distribution coefficients at cross-sections 1 and 2 (Figure 4.4)

$A_{n2}$ = gross water area (m$^2$) in constriction measured below normal stage

$V_{n2}$ = average velocity (m/s) in constriction or $Q/A_{n2}$

$A_4$ = water area (m$^2$) at section 4 (Figure 4.4) where normal stage is re-established

$A_1$ = total water area (m$^2$) at section 1 (Figure 4.4), including that produced by the backwater

$g$ = acceleration of gravity, (m/s$^2$)

The backwater coefficient, denoted as K*, depends on several factors that are considered in its evaluation:

- Bridge Opening Ratio: The proportion of the total flow area available at the bridge opening.
- Pier Characteristics: The number, size, shape, and orientation of the piers in the bridge's construction.
- Eccentricity or Asymmetry: The location of the bridge in relation to the floodplain, whether it is centrally aligned or offset.
- Bridge Skew: The angle at which the bridge is oriented relative to the flow direction.

To determine the total K*, incremental K values are calculated for each contributing factor using design charts, and these values are combined to compute the overall backwater effect.

## 7.2 Design Procedure

The following steps outline the procedure for determining the bridge waterway check:

1. Determine the Magnitude of Flow: Calculate the design flow at the site for the specified recurrence interval.
2. Establish Stage-Discharge Curve: Develop the stage-discharge relationship for the stream at the bridge site.
3. Determine Stage Height: Use the stage-discharge curve to identify the stage height corresponding to the design discharge.
4. Identify Flow Type: Assess the type of flow encountered at the site.
5. Calculate Backwater: Use the relevant procedure for the identified flow type to compute backwater effects.
6. Check Bridge Deck Level: Verify the bridge deck soffit level considering the stage height and backwater for the design discharge.

This systematic approach ensures a hydraulically efficient and safe bridge design. Based on above design procedure detail hydraulic calculations have been performed and presented in the Appendix A.

## 7.3 Topographical Survey Data

Topographical survey data from IO Geomatics Ltd. (2024) has been used to develop the hydraulic model. The data includes river cross sections and the stream layout.

**Table 7-1 - River Cross sections**

| | | |
|---|---|---|
| CH 163.09 | Upstream | circa 163 m upstream from the bridge inlet |
| CH 150 | | circa 150 m upstream from the bridge inlet |
| CH 130 | | circa 130m upstream from the bridge inlet |
| CH 110 | | circa 110m upstream from the bridge inlet |
| CH 90 | | circa 90m upstream from the bridge inlet |
| CH 70 | | circa 70m upstream from the bridge inlet |
| CH 50 | | circa 50m upstream from the bridge inlet |
| CH 30 | | circa 30m upstream from the bridge inlet |
| CH 10 | | circa 10m upstream from the bridge inlet |
| CH 0+00 US | Bridge | Inlet |
| Ch 0+00 DS | | Outlet |
| CH 10 | Downstream | circa10 m upstream from the bridge inlet |
| CH 30 | | circa30 m upstream from the bridge inlet |
| CH 50 | | circa50 m upstream from the bridge inlet |
| CH 70 | | circa 70m upstream from the bridge inlet |
| CH 90 | | circa 90m upstream from the bridge inlet |
| CH 110 | | circa110m upstream from the bridge inlet |
| CH 130 | | circa 130m upstream from the bridge inlet |
| CH 150 | | circa 150 m upstream from the bridge inlet |

## 7.4 Channel and Associated Bank Roughness Values

The selection of an appropriate Manning’s ‘n’ coefficient is crucial for accurately calculating water surface elevations. Manning’s ‘n’ is highly variable and influenced by several factors, including surface roughness, vegetation, channel irregularities, alignment, scour and deposition, obstructions, channel size and shape, stage and discharge, seasonal changes, temperature, and the presence of suspended material or bedload.

For the Strade River Bridge, the Manning’s roughness coefficient (n) was selected based on the observed site conditions. The channel exhibits some weeds and light brush along the banks, which slightly increases the flow resistance. In accordance with standard hydraulic guidelines, a Manning's n value of 0.04 was adopted to account for these conditions. Sensitivity analysis was conducted by varying the Manning’s ‘n’ values within a reasonable range to evaluate the impact on flow calculations.

See Figure 7-3 below for a view of the channel upstream of the bridge.

**Figure 7-3 – Channel upstream of the bridge**

# 7.5 Hydraulic Assessment

The hydraulic assessment for Strade River Bridge was conducted to evaluate the flow behaviour under the design flood conditions and ensure compliance with regulatory requirements. As a conservative measure and to future proof the proposed structure against any future works to be masonry arch bridge upstream, the beneficial effects to the flow caused by the masonry arch bridge were not considered in the assessment.

The design flood flow, corresponding to a 1% AEP (1 in 100-year event) with climate change (CC) allowance, was determined as $Q_{100CC}$. The stage height for this flow was assessed, and the Froude number was calculated to be less than 1, indicating subcritical flow conditions. This confirmed that the bridge constriction creates either Type 1 or Type 2 flow scenarios as shown in Figure 7-1.

The backwater effects were analysed for both flow types by incorporating various bridge attributes, including pier dimensions, opening characteristics, and the eccentricity of the bridge in relation to the floodplain. The assessment of the backwater height confirmed that bridge constriction is creating Type 1 flow. The analysis revealed a backwater height of 0.15m for Type 1 flow, leading to a design flood level (1% AEP incorporating Climate change effects) of 18.38m for the existing bridge.

The 18.38mOD design flood level determined by the analysis for the existing bridge is 0.28m above the existing bridge soffit level of 18.1mOD.

The design flood level determined by the analysis for the proposed single span bridge with the existing pier taken down and existing apron retained is 18.32mOD. Following consultation with IFI on the reduction in concrete apron height the design flood level reduces to 18.31mOD for the new 300mm concrete apron height.

Other options considered at option stage for the proposed structure was the full structure replacement and the widening of the existing bridge opening. The optimum span opening was found to be 11.6m based on the existing channel constraints. Due to the channel profile a significant reduction in the design flood level for the wider bridge opening was not determined however, with the analysis determining a design flood level of 18.24mOD, only an 80mm reduction compared to the proposed structure.

# 8. Conclusion

The hydrology and hydraulics study for Strade River Bridge has been undertaken in line with OPW requirements. The bridge has been assessed to pass a 1% Annual Exceedance Probability (AEP) flood flow, equivalent to a 1 in 100-year event with a factor also included for climate change.

The assessment utilised the $Q_{100cc}$ flow derived from the Small Catchment equation for the $Q_{MED}$, where the flow values for $Q_{Med}$, $Q_{100}$, and $Q_{100cc}$ are 9.712 m³/s, 30.036 m³/s, and 36.043 m³/s, respectively.

The existing bridge superstructure is proposed to be demolished with a new single span replacement deck constructed to align with the retained substructure. New independent foundation supports would be located behind the existing abutment walls with the proposed foundations comprising reinforced concrete bored cast in place piles and pilecaps. The proposed works ensures the protection of the existing watercourse during construction by locating the new supports behind the existing abutment walls.

The existing pier and concrete apron are to be demolished with a new reduced height concrete apron installed to maintain the existing low flow channel in line with IFI requirements.

The hydraulic assessment determined a 1% AEP flood level, including climate change effects, of 18.31mOD for the proposed bridge and reduced height apron. As the design flood level is 0.21m higher than the existing soffit level and the structural depth for the proposed single span arrangement is greater than the existing 2 span bridge deck the existing road level would be required to be raised at the bridge location in order to meet the design flood level.

The provision of a minimum freeboard of 300mm above the design flood level as per standard OPW requirements would require the road level on the new bridge to be raised by c.700mm. Due to existing site constraints with properties and entrances on both approaches, increasing the road level by c.700mm is not feasible and would result in road safety issues due to the gradients required and also create a possible damming effect for any future flood events upstream of the bridge.

A c.400mm increase in road level could be achieved over the available carriageway realignment length to meet the design flood level of 18.31mOD. This c.300mm reduction in the new road level would alleviate much of the possible damming effect caused by the new road level and minimise the change to the vertical alignment of the N58 National Secondary Road. This would mean that the 300mm freeboard requirement would not be provided, as outlined in recent consultation with OPW. The bridge soffit level of 18.32mOD proposed at the time of consultation based on the existing concrete apron would be maintained to provide a minimal freeboard of 10mm.

The proposed soffit level of the new bridge is 220mm above the soffit of the existing bridge and provides a single span opening with the pier removed to improve flow through the structure. The proposed bridge deck replacement therefore does not add any additional constraint to the existing channel with the upstream masonry arch bridge remaining the primary constraint. As the design flood level determined by hydraulic assessment did not consider beneficial effects from the masonry arch bridge the proposed bridge structure is also future proofed against any future works to the masonry arch bridge.

# APPENDICES

# Appendix A. Peak Design Flow Assessment

**OPW**

**FEMI Flood Estimation Report**

| | |
|---|---|
| **CLIENT:** | OPW |
| **PROJECT:** | Strade River Bridge |
| **DOC. TITLE** | Strade River Bride-Hydraulic Assessment |
| **REFERENCE:** | 0 0 |
| **Checked:** YS | **SUBJECT:** CALCULATION OF QMED & PEAK DESIGN |
| **Approved:** MG | FLOWS IN UNGAUGED CATCHMENTS |

## A Selection of the Subject Site

A1 Ungauged Node ID: 34_3826_6

A2 Ungauged Node Catchment Descriptors:

| Physical Catchment Descriptors | | | |
|---|---|---|---|
| AREA | 22.46 | Node East | 125725 |
| BFIsoils | 0.47 | Node North | 297494 |
| SAAR | 1184.54 | Centroid East | 127520 |
| FARL | 1.00 | Centroid North | 292130 |
| DRAIND | 1.83 | ALLUV | 0.00 |
| S1085 | 7.83 | ARTDRAIN | 0.00 |
| ARTDRAIN2 | 0.27 | FOREST | 0.00 |
| URBEXT | 0.00 | | |

## B Module 1: Estimation of the Index Flood (QMED)

| | |
|---|---|
| B.1. Estimation of QMED without the use of a pivotal site | 6.73 |
| B.2. Estimation of QMED by using one pivotal site: 30020 | 7.97 |
| B.3. Estimation of QMED using three pivotal sites: 30020, 31002, 36021 | 9.71 |
| B.4. Final chosen QMED estimate: Using 3 Pivotal Sites 30020, 31002, 36021 | 9.71 |

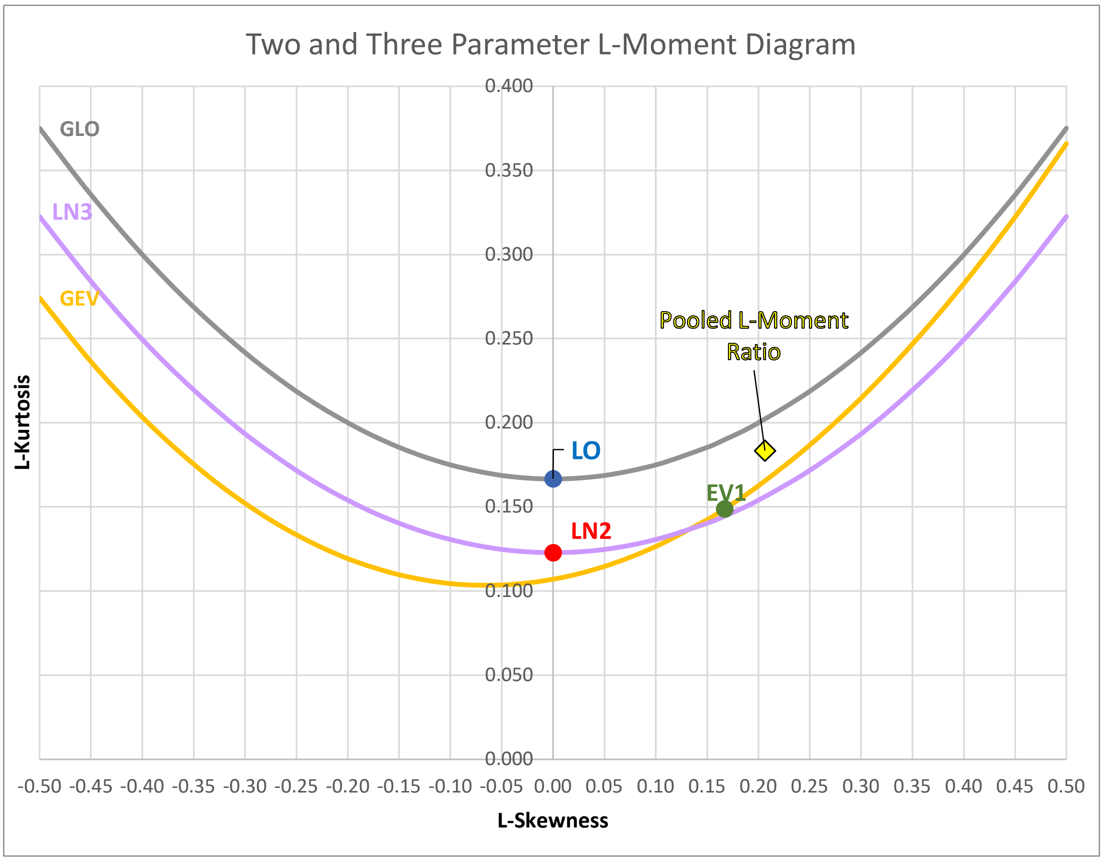
## C Module 2: Estimation of the flood growth factors and design flood magnitudes

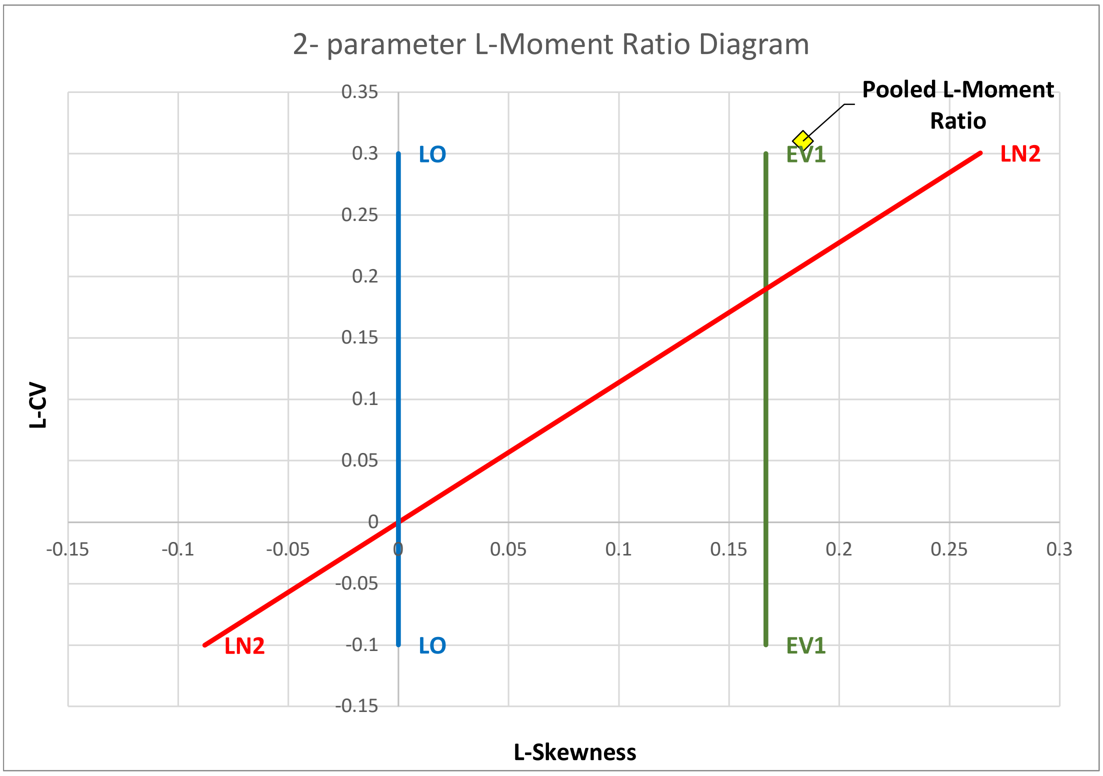
**C.1. Selection of Pooling Group for flood frequency analysis**

| station no. | Location | similarity measure | No. of Yrs of data | t2 L-CV | t3 L-Skewness | t4 L-Kurtosis |
|---|---|---|---|---|---|---|
| 30020 | BALLYHAUNIS | 0.05 | 34 | 0.184 | 0.310 | 0.263 |
| 34024 | KILTIMAGH | 1.26 | 44 | 0.090 | 0.105 | 0.133 |
| 26010 | RIVERSTOWN | 1.31 | 53 | 0.107 | 0.186 | 0.143 |
| 23001 | INCH BR. | 1.47 | 51 | 0.176 | 0.106 | 0.171 |
| 34009 | CURRAGHBONAUN | 1.59 | 51 | 0.097 | 0.168 | 0.188 |
| 25040 | ROSCREA | 1.60 | 37 | 0.154 | 0.120 | 0.081 |
| 30021 | CHRISTINA'S BR. | 1.68 | 45 | 0.140 | 0.055 | 0.259 |
| 34011 | GNEEVE BRIDGE | 1.70 | 48 | 0.105 | 0.149 | 0.145 |
| 35001 | BALLYNACARROW | 1.85 | 51 | 0.133 | 0.192 | 0.243 |
| 24005 | ATHLACCA | 1.87 | 35 | 2.670 | 0.471 | 0.447 |
| 35071 | LAREEN | 1.96 | 48 | 0.148 | 0.247 | 0.254 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**C.2. Selection of the best fit flood frequency distribution to the pooled data**

L-Moment Ratio Diagrams:



Final Growth Factors and Design Flows:

| EV1 | | |
|---|---|---|
| **Return Period (T)** | **Growth Factors** | **Design Flows** |
| **1.3** | **0.630** | **6.115** |
| **2** | **1.000** | **9.712** |
| **5** | **1.560** | **15.153** |
| **10** | **1.931** | **18.755** |
| **20** | **2.287** | **22.211** |
| **25** | **2.400** | **23.307** |
| **30** | **2.492** | **24.199** |
| **35** | **2.569** | **24.951** |
| **50** | **2.748** | **26.684** |
| **100** | **3.093** | **30.036** |
| **200** | **3.437** | **33.375** |
| **500** | **3.890** | **37.781** |
| **1000** | **4.233** | **41.111** |

| | | | |
|---|---|---|---|
| Custom Return Period | 100 | 3.093 | 30.036 |

## D Module 3: Generation of Design Hydrograph Shape Parameters

### D.1. Generation of Initial Design Hydrograph Shape Parameters

Catchment Wetness Indicator **(CWI)** 123

Baseflow: 0.79 $m^3/s$

| n | Tr (hours) | C (hours) |
|---|---|---|
| 6.61 | 18.41 | 19.25 |

### D.2. Selection of most hydrologically similar catchments

| | Station No. | Dij similarity measure | n | Tr | C |
|---|---|---|---|---|---|
| 1st most similar | 23012 | 0.242 | 9.930 | 20.125 | 9.045 |
| 2nd most similar | 35002 | 0.482 | 9.252 | 16.232 | 5.380 |
| 3rd most similar | 16013 | 0.683 | 10.000 | 4.795 | 1.716 |

D.2. Option 1: Adjusted parameters using most hydrologically similar catchment, 23012

| n | Tr | C |
|---|---|---|
| 8.330 | 20.865 | 9.237 |

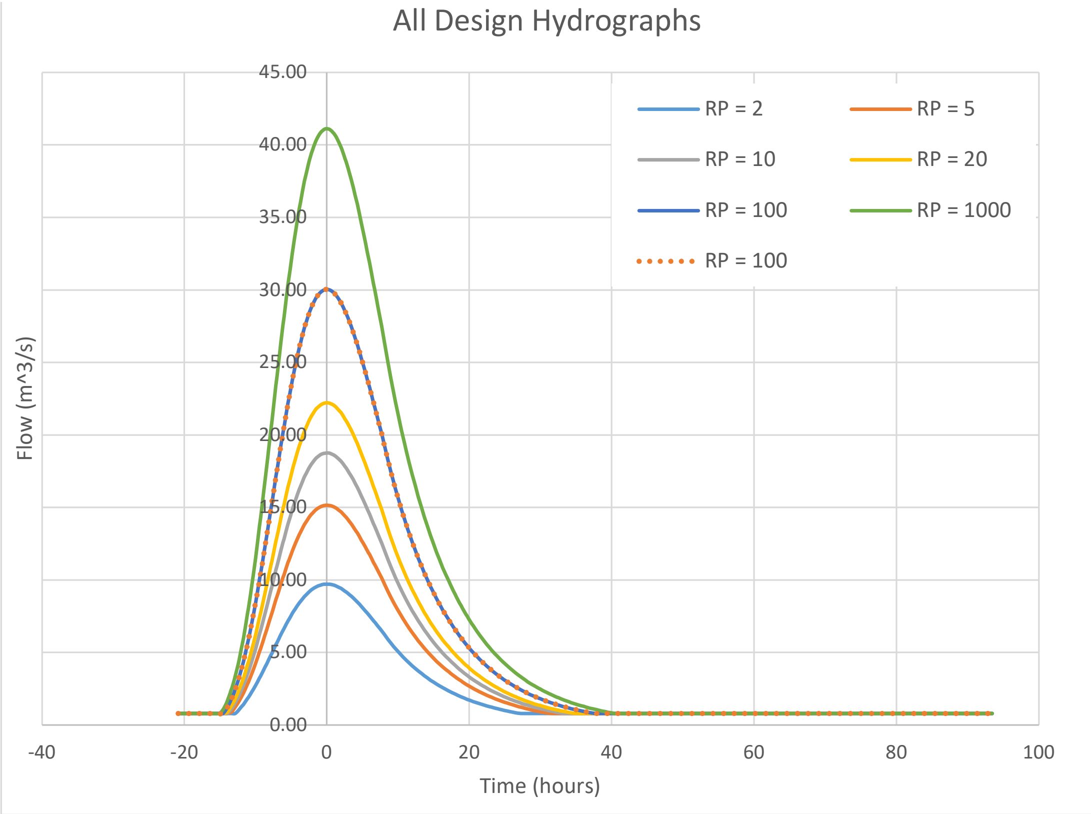
D.2. Option 2: Adjusted Shape parameters using 3 no. Pivotal Sites, 23012, 35002, 16013

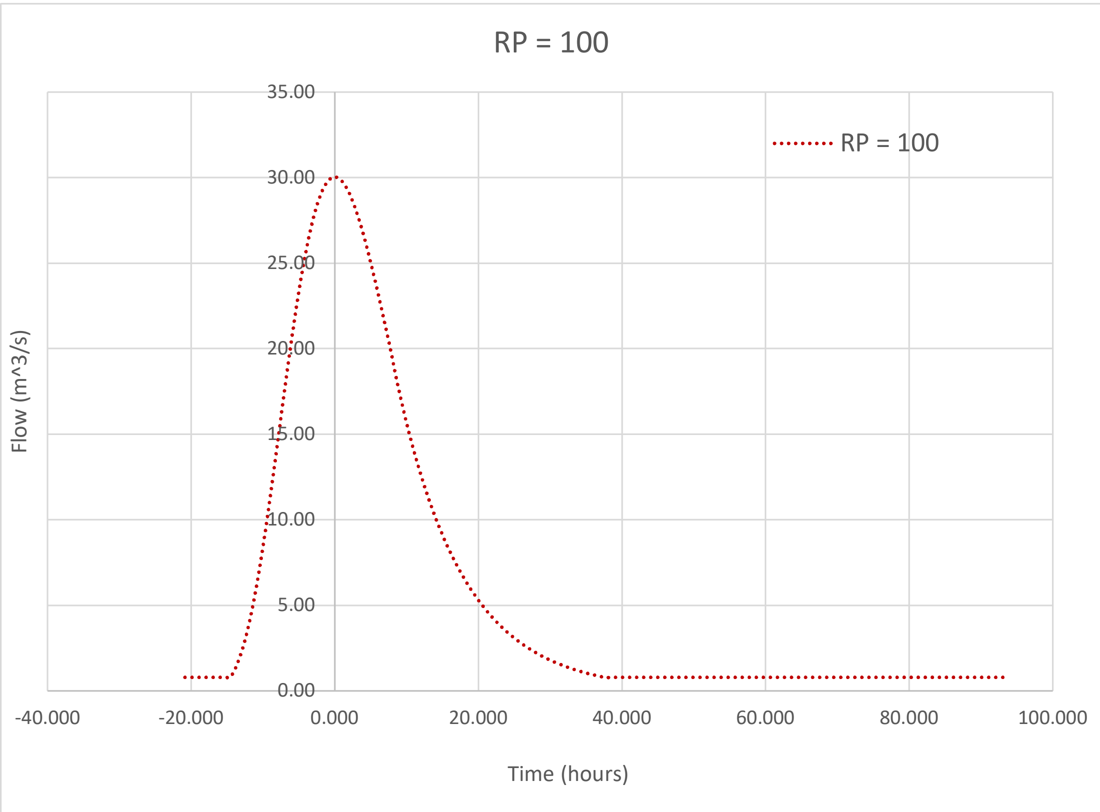
| n | Tr | C |
|---|---|---|
| 7.487 | 16.982 | 7.260 |

Chosen parameter selection method:

**Adjusted parameters using most hydrologically similar catchment, 23012**

| D.3. Final Hydrograph Parameters: | **n** | **Tr** | **C** |
|---|---|---|---|
| | **8.330** | **20.865** | **9.237** |


All Design Hydrographs
RP = 2
RP = 5
RP = 10
RP = 20
RP = 100
RP = 1000
RP = 100
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Flow (m^3/s)
-40
-20
0
20
40
60
80
100
Time (hours)


RP = 100
RP = 100
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Flow (m^3/s)
-40.000
-20.000
0.000
20.000
40.000
60.000
80.000
100.000
Time (hours)

Hydrograph Plot Data:

| Time (Hours) | RP = 2 | RP = 5 | RP = 10 | RP = 20 | RP = 100 | RP = 1000 | Custom RP<br>RP = 100 |
|---|---|---|---|---|---|---|---|
| -20.865 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -20.293 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -19.722 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -19.150 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -18.579 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -18.008 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -17.436 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -16.865 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -16.293 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -15.722 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -15.150 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| -14.579 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 1.044 | 0.788 |
| -14.008 | 0.788 | 0.788 | 0.788 | 0.874 | 1.181 | 1.617 | 1.181 |
| -13.436 | 0.788 | 0.877 | 1.085 | 1.285 | 1.738 | 2.379 | 1.738 |
| -12.865 | 0.791 | 1.235 | 1.528 | 1.810 | 2.448 | 3.350 | 2.448 |
| -12.293 | 1.074 | 1.675 | 2.073 | 2.455 | 3.320 | 4.545 | 3.320 |
| -11.722 | 1.410 | 2.199 | 2.722 | 3.224 | 4.360 | 5.967 | 4.360 |
| -11.151 | 1.799 | 2.806 | 3.473 | 4.113 | 5.563 | 7.614 | 5.563 |
| -10.579 | 2.237 | 3.491 | 4.321 | 5.117 | 6.919 | 9.471 | 6.919 |
| -10.008 | 2.720 | 4.245 | 5.254 | 6.222 | 8.414 | 11.516 | 8.414 |
| -9.436 | 3.241 | 5.058 | 6.260 | 7.413 | 10.025 | 13.722 | 10.025 |
| -8.865 | 3.792 | 5.917 | 7.323 | 8.673 | 11.728 | 16.053 | 11.728 |
| -8.293 | 4.363 | 6.808 | 8.426 | 9.979 | 13.494 | 18.470 | 13.494 |
| -7.722 | 4.944 | 7.715 | 9.549 | 11.308 | 15.292 | 20.931 | 15.292 |
| -7.151 | 5.526 | 8.622 | 10.672 | 12.638 | 17.091 | 23.393 | 17.091 |
| -6.579 | 6.098 | 9.515 | 11.777 | 13.946 | 18.860 | 25.814 | 18.860 |
| -6.008 | 6.651 | 10.377 | 12.844 | 15.210 | 20.569 | 28.153 | 20.569 |
| -5.436 | 7.175 | 11.195 | 13.856 | 16.409 | 22.190 | 30.373 | 22.190 |
| -4.865 | 7.663 | 11.957 | 14.799 | 17.526 | 23.700 | 32.440 | 23.700 |
| -4.293 | 8.108 | 12.651 | 15.659 | 18.544 | 25.077 | 34.325 | 25.077 |
| -3.722 | 8.505 | 13.270 | 16.425 | 19.451 | 26.304 | 36.003 | 26.304 |
| -3.151 | 8.849 | 13.806 | 17.089 | 20.237 | 27.367 | 37.458 | 27.367 |
| -2.579 | 9.136 | 14.255 | 17.644 | 20.895 | 28.256 | 38.675 | 28.256 |
| -2.008 | 9.366 | 14.613 | 18.087 | 21.419 | 28.965 | 39.646 | 28.965 |
| -1.436 | 9.536 | 14.879 | 18.417 | 21.810 | 29.494 | 40.370 | 29.494 |
| -0.865 | 9.649 | 15.055 | 18.634 | 22.068 | 29.842 | 40.846 | 29.842 |
| -0.293 | 9.704 | 15.142 | 18.742 | 22.195 | 30.014 | 41.081 | 30.014 |
| 0.278 | 9.705 | 15.143 | 18.743 | 22.197 | 30.016 | 41.085 | 30.016 |
| 0.849 | 9.654 | 15.063 | 18.645 | 22.080 | 29.859 | 40.869 | 29.859 |
| 1.421 | 9.555 | 14.908 | 18.453 | 21.853 | 29.551 | 40.448 | 29.551 |
| 1.992 | 9.411 | 14.684 | 18.175 | 21.524 | 29.106 | 39.839 | 29.106 |
| 2.564 | 9.227 | 14.397 | 17.820 | 21.103 | 28.537 | 39.060 | 28.537 |
| 3.135 | 9.007 | 14.054 | 17.395 | 20.600 | 27.857 | 38.130 | 27.857 |
| 3.706 | 8.756 | 13.662 | 16.910 | 20.026 | 27.081 | 37.067 | 27.081 |
| 4.278 | 8.478 | 13.229 | 16.374 | 19.391 | 26.222 | 35.891 | 26.222 |
| 4.849 | 8.178 | 12.761 | 15.794 | 18.705 | 25.294 | 34.621 | 25.294 |
| 5.421 | 7.861 | 12.265 | 15.181 | 17.978 | 24.311 | 33.276 | 24.311 |
| 5.992 | 7.529 | 11.747 | 14.540 | 17.219 | 23.285 | 31.872 | 23.285 |
| 6.564 | 7.187 | 11.214 | 13.880 | 16.438 | 22.229 | 30.426 | 22.229 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7.135 | 6.839 | 10.671 | 13.209 | 15.642 | 21.153 | 28.953 | 21.153 |
| 7.706 | 6.489 | 10.124 | 12.531 | 14.840 | 20.068 | 27.468 | 20.068 |
| 7.706 | 6.489 | 10.124 | 12.531 | 14.840 | 20.068 | 27.468 | 20.068 |
| 8.564 | 5.914 | 9.227 | 11.420 | 13.525 | 18.289 | 25.034 | 18.289 |
| 9.421 | 5.390 | 8.409 | 10.408 | 12.326 | 16.669 | 22.815 | 16.669 |
| 10.278 | 4.912 | 7.664 | 9.486 | 11.234 | 15.191 | 20.793 | 15.191 |
| 11.135 | 4.477 | 6.985 | 8.645 | 10.238 | 13.845 | 18.950 | 13.845 |
| 11.992 | 4.080 | 6.366 | 7.879 | 9.331 | 12.618 | 17.271 | 12.618 |
| 12.849 | 3.718 | 5.802 | 7.181 | 8.504 | 11.500 | 15.740 | 11.500 |
| 13.706 | 3.389 | 5.287 | 6.544 | 7.750 | 10.481 | 14.345 | 10.481 |
| 14.564 | 3.088 | 4.819 | 5.965 | 7.063 | 9.552 | 13.074 | 9.552 |
| 15.421 | 2.815 | 4.392 | 5.436 | 6.437 | 8.705 | 11.915 | 8.705 |
| 16.278 | 2.565 | 4.003 | 4.954 | 5.867 | 7.934 | 10.860 | 7.934 |
| 17.135 | 2.338 | 3.648 | 4.515 | 5.347 | 7.231 | 9.897 | 7.231 |
| 17.992 | 2.131 | 3.325 | 4.115 | 4.873 | 6.590 | 9.020 | 6.590 |
| 18.849 | 1.942 | 3.030 | 3.750 | 4.441 | 6.006 | 8.221 | 6.006 |
| 19.706 | 1.770 | 2.761 | 3.418 | 4.048 | 5.474 | 7.492 | 5.474 |
| 20.563 | 1.613 | 2.517 | 3.115 | 3.689 | 4.989 | 6.828 | 4.989 |
| 21.421 | 1.470 | 2.294 | 2.839 | 3.362 | 4.547 | 6.223 | 4.547 |
| 22.278 | 1.340 | 2.090 | 2.587 | 3.064 | 4.144 | 5.672 | 4.144 |
| 23.135 | 1.221 | 1.905 | 2.358 | 2.793 | 3.776 | 5.169 | 3.776 |
| 23.992 | 1.113 | 1.736 | 2.149 | 2.545 | 3.442 | 4.711 | 3.442 |
| 24.849 | 1.014 | 1.582 | 1.959 | 2.320 | 3.137 | 4.293 | 3.137 |
| 25.706 | 0.924 | 1.442 | 1.785 | 2.114 | 2.859 | 3.913 | 2.859 |
| 26.563 | 0.842 | 1.314 | 1.627 | 1.927 | 2.605 | 3.566 | 2.605 |
| 27.421 | 0.788 | 1.198 | 1.483 | 1.756 | 2.374 | 3.250 | 2.374 |
| 28.278 | 0.788 | 1.092 | 1.351 | 1.600 | 2.164 | 2.962 | 2.164 |
| 29.135 | 0.788 | 0.995 | 1.232 | 1.458 | 1.972 | 2.700 | 1.972 |
| 29.992 | 0.788 | 0.907 | 1.122 | 1.329 | 1.797 | 2.460 | 1.797 |
| 30.849 | 0.788 | 0.826 | 1.023 | 1.211 | 1.638 | 2.242 | 1.638 |
| 31.706 | 0.788 | 0.788 | 0.932 | 1.104 | 1.493 | 2.044 | 1.493 |
| 32.563 | 0.788 | 0.788 | 0.850 | 1.006 | 1.361 | 1.862 | 1.361 |
| 33.420 | 0.788 | 0.788 | 0.788 | 0.917 | 1.240 | 1.697 | 1.240 |
| 34.278 | 0.788 | 0.788 | 0.788 | 0.836 | 1.130 | 1.547 | 1.130 |
| 35.135 | 0.788 | 0.788 | 0.788 | 0.788 | 1.030 | 1.410 | 1.030 |
| 35.992 | 0.788 | 0.788 | 0.788 | 0.788 | 0.939 | 1.285 | 0.939 |
| 36.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.856 | 1.171 | 0.856 |
| 37.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 1.067 | 0.788 |
| 38.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.973 | 0.788 |
| 39.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.886 | 0.788 |
| 40.278 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.808 | 0.788 |
| 41.135 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 41.992 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 42.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 43.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 44.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 45.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 46.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 47.135 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 47.992 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 48.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 49.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 50.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 51.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 52.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 53.135 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 53.992 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 54.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 55.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 56.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 57.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 58.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 59.134 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 59.992 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 60.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 61.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 62.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 63.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 64.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 65.134 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 65.992 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 66.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 67.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 68.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 69.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 70.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 71.134 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 71.991 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 72.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 73.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 74.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 75.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 76.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 77.134 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 77.991 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 78.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 79.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 80.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 81.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 82.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 83.134 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 83.991 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 84.849 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 85.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 86.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 87.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 88.277 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 89.134 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 89.991 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 90.848 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 91.706 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 92.563 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 93.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |
| 93.420 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 |

# Appendix B. Bridge Hydraulic Assessment - Existing Structure

| Project | Mayo Bridges | Date | ######## | | |
|---|---|---|---|---|---|
| Bridge No | Strade River | Designed | YS | | |
| Place | Mayo | Checked | MG | | |

Design Discharge Q 36.0432 m3/s
Average Bed Slope S0 0.002 m/m

**Calculaton of Unconstricted Flood state**

Stage Ht 18.2

| Sub Section | Mannings Coefficient n | a, Area ( m2) | p , Weted Perimeter (m) | m= a/p | $k = am^{2/3}/n$ | $q=kS_0^{1/2}$ | v=q/a | $qv^2$ |
|---|---|---|---|---|---|---|---|---|
| Section A ( Qa) | 0.04 | 1.2079 | 2.1231 | 0.568932 | 20.73 | 0.93 | 0.77 | 0.55 |
| Section B ( Qb) | 0.04 | 17.1013 | 8.3004 | 2.060298 | 692.24 | 30.96 | 1.81 | 101.45 |
| Section C ( Qc) | 0.04 | 1.2827 | 2.9474 | 0.435197 | 65.92 | 2.95 | 2.30 | 15.57 |
| | | 19.5919 | | | 778.89 | 34.83 | | 117.57 |

Stage Ht 18.24

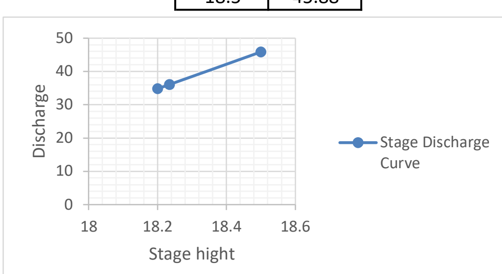
| Sub Section | Mannings Coefficient n | a, Area ( m2) | p , Weted Perimeter (m) | m= a/p | $k = am^{2/3}/n$ | $q=kS_0^{1/2}$ | v=q/a | $qv^2$ |
|---|---|---|---|---|---|---|---|---|
| Section A ( Qa) | 0.04 | 1.2594 | 2.17 | 0.580369 | 21.91 | 0.98 | 0.78 | 0.59 |
| Section B ( Qb) | 0.04 | 17.2943 | 8.201 | 2.108907 | 711.02 | 31.80 | 1.84 | 107.49 |
| Section C ( Qc) | 0.04 | 1.38 | 3.0926 | 0.446226 | 73.23 | 3.28 | 2.37 | 18.45 |
| | | **19.9337** | | | **806.16** | **36.05** | | **126.53** |

Stage Ht 18.50

| Sub Section | Mannings Coefficient n | a, Area ( m2) | p , Weted Perimeter (m) | m= a/p | $k = am^{2/3}/n$ | $q=kS_0^{1/2}$ | v=q/a | $qv^2$ |
|---|---|---|---|---|---|---|---|---|
| 0.959 | 0.04 | 1.7707 | 2.6074 | 0.679106 | 34.20 | 1.53 | 0.86 | 1.14 |
| Section B ( Qb) | 0.04 | 19.2678 | 8.285 | 2.325625 | 845.54 | 37.81 | 1.96 | 145.64 |
| Section C ( Qc) | 0.04 | 2.2416 | 4.2095 | 0.53251 | 146.10 | 6.53 | 2.91 | 55.51 |
| | | 23.2801 | | | 1025.84 | 45.88 | | 202.29 |

| Stage ht | Q |
|---|---|
| 18.2 | 34.83318 |
| 18.235 | 36.05 |
| 18.5 | 45.88 |

**Flood Stage Level**
18.23



| | | | | | | |
|---|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | | |
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

| | | |
|---|---|---|
| Flood Stage Level | **18.24** | msl |
| Width at Flood Stage | 11.5932 | m |
| River Bed Level | 15.46 | msl |
| | | |
| Bridge Span | 7.3 | m |
| No of Piers | 1 | Nos |
| Pier Width Wp | 1.5 | m |
| Flow Approach Angle | 15 | degrees |

**Flow Type Determination**

Frode Number

$$Fr_n = [(\frac{Q^2 B}{g A_n^3})^{1/2}$$

0.44 <1

Flow is type 1 or type 2

**Specific Energy of unconstricted normal Flow**

$$y_n = \text{Flood stage level - river bed level}$$

2.78 m

$$V_n = \frac{Q}{A_n}$$

1.81 m/s

$$E_{sn} = y_n + \frac{V_n^2}{2g}$$

**2.94 m**

Calculate Specific energy of constrictied flow critical depth

$$y_{2c} = [(\frac{Q^2}{gb^2})^{1/3}$$

1.35 m

$$V_{2c} = \frac{Q}{y_{2c} b}$$

3.65 m/s

$$E_{sc} = y_{2c} + \frac{V_{2c}^2}{2g}$$

**2.03 m**

Calculate bridge opening ratio

$$M = \frac{Q_b}{Q}$$

0.88

Calculate Velocity Head Co efficient

$$\alpha_1 = \frac{\Sigma(qv^2)}{Q\ V_n^2}$$

1.07

| Project | Mayo Bridges | Date | ######## | | | |
|---|---|---|---|---|---|---|
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

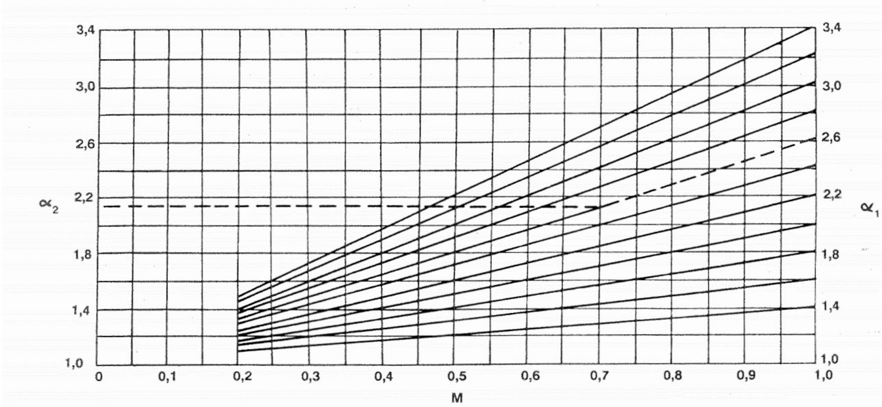
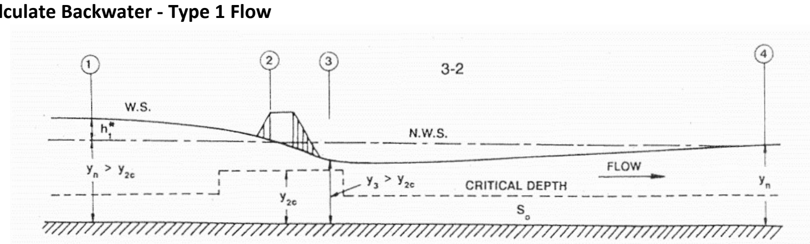


FIGURE 3.5 : VELOCITY HEAD COEFFICIENT IN CONSTRUCTION (BUREAU OF PUBLIC ROADS, 1970)

$\alpha_2$ = **1.1**

**Calculate Backwater - Type 1 Flow**



A - TYPE I FLOW (SUBCRITICAL)

**Pier Effect**

Projected area of the pier

$$A_p = N_p \bar{y} W_p = N_p \frac{A_{n2}}{b} W_p$$

**5.43** m2

An2 **19.622** m2

$$J = \frac{A_p}{A_{n2}}$$

0.27673

Eccentricity

$$e = 1 - \frac{Q_a}{Q_c}$$

**0.700862** check for Qc>QA othervise QC/Q

| | | | | | | |
|---|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | | |
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

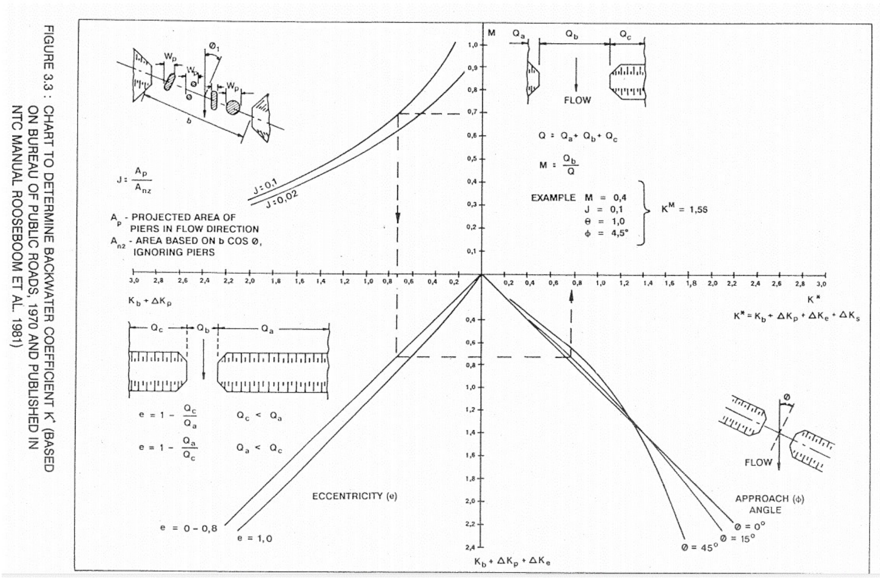



FIGURE 3.3 : CHART TO DETERMINE BACKWATER COEFFICIENT K* (BASED ON BUREAU OF PUBLIC ROADS, 1970 AND PUBLISHED IN NTC MANUAL ROOSEBOOM ET AL. 1981)

| | | |
|---|---|---|
| | M | 0.88 |
| | J | 0.27673 |
| | e | 0.70 |
| Apprach Anges | shy | **15** |
| | $K^*$ | **0.7** |

Approximate Backwater

An2 **19.62**

$$V_{n2} = \frac{Q}{A_{n2}}$$

1.78 m/s

$$h_1^{*1} = K^* \alpha_2 \frac{V_{n2}^2}{2g}$$

0.12 m

$$A_1 = A_n + h_1^{*1} B$$

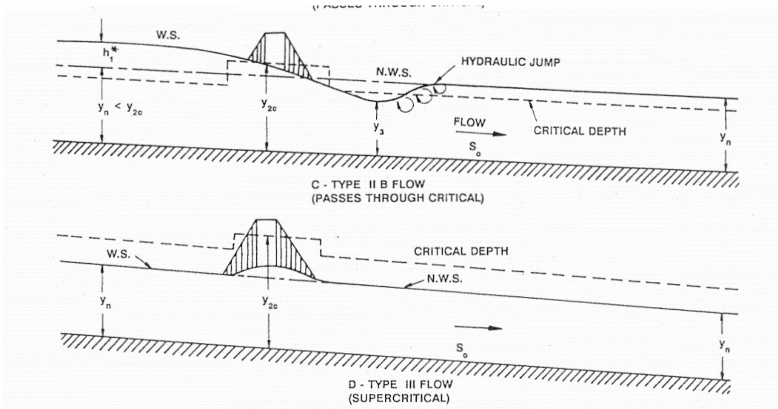
21.3748 m2

$$h_1^* = h_1^{*1} + \alpha_1 \left[\left(\frac{A_{n2}}{A_4}\right)^2 - \left(\frac{A_{n2}}{A_1}\right)^2\right] \frac{V_{n2}^2}{2g} \quad (Eqn.\ 3.1)$$

**0.15 m**

| Project | Mayo Bridges | Date | ######## | | | |
|---|---|---|---|---|---|---|
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

**Calculate Backwater - Type ii Flow**




$$b_c = (b - \Sigma W_p)$$

5.8 m

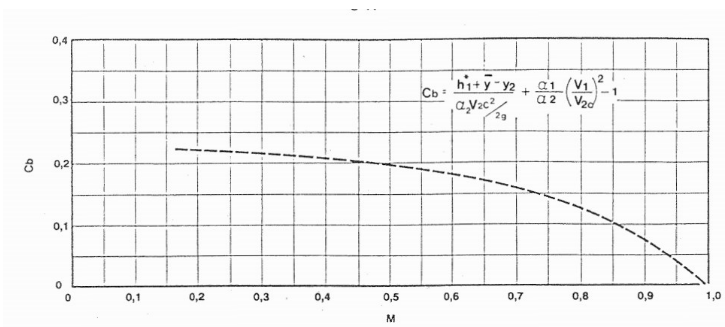



FIGURE 3.8 : DISCHARGE COEFFICIENT FOR TYPE II FLOW
(BUREAU OF PUBLIC ROADS, 1970)

Cb **0.08**

$$y_{2c} = \left(\frac{Q^2}{g b_c^2}\right)^{1/3}$$

1.58

$$y = \frac{A_{n2}}{b}$$

2.69 m

| | | | | | |
|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | |
| Bridge No | Strade River | Designed | YS | | |
| Place | Mayo | Checked | MG | | |

$$V_1 = \frac{Q}{A_n}$$

1.81 m/s

$$V_{2c} = (g.y_{2c})^{0,5}$$

3.94 m/s

$$h_1^* = \alpha_2 \frac{V_{2c}^2}{2g}(C_b + 1) - \alpha_1 \frac{V_1^2}{2g} + y_{2c} - \bar{y}$$

0.938069 0.178882 1.58 2.78

-0.437

$$A_1 = A_n + h_1^* B$$

14.87243 m2

V1 2.42 m/s

$$h_1^* = \alpha_2 \frac{V_{2c}^2}{2g}(C_b + 1) - \alpha_1 \frac{V_1^2}{2g} + y_{2c} - \bar{y}$$

0.938069 0.32135 1.58 2.78

**h1** **-0.58**

| | |
|---|---|
| Stage height Normal Water Level | 18.24 |
| Backwater height | 0.15 |
| High flood level for Design Discharge | 18.38 |
| Bridge Soffit | 18.1 |
| Free board | **-0.28** |

# Appendix C. Bridge Hydraulic Assessment - Proposed Structure

| Project | Mayo Bridges | Date | ######## | | |
|---|---|---|---|---|---|
| Bridge No | Strade River | Designed | YS | | |
| Place | Mayo | Checked | MG | | |

Design Discharge Q 36.0432 m3/s

Average Bed Slope S0 0.002 m/m

**Calculaton of Unconstricted Flood state**

Stage Ht 18.2

| Sub Section | Manningss Coefficient n | a, Area ( m2) | p , Weted Perimeter (m) | m= a/p | $k = am^{2/3}/n$ | $q=kS_0^{1/2}$ | v=q/a | $qv^2$ |
|---|---|---|---|---|---|---|---|---|
| Section A ( Qa) | 0.04 | 1.2079 | 2.1231 | 0.568932 | 20.73 | 0.93 | 0.77 | 0.55 |
| Section B ( Qb) | 0.04 | 17.1013 | 8.3004 | 2.060298 | 692.24 | 30.96 | 1.81 | 101.45 |
| Section C ( Qc) | 0.04 | 1.2827 | 2.9474 | 0.435197 | 65.92 | 2.95 | 2.30 | 15.57 |
| | | 19.5919 | | | 778.89 | 34.83 | | 117.57 |

Stage Ht 18.24

| Sub Section | Manningss Coefficient n | a, Area ( m2) | p , Weted Perimeter (m) | m= a/p | $k = am^{2/3}/n$ | $q=kS_0^{1/2}$ | v=q/a | $qv^2$ |
|---|---|---|---|---|---|---|---|---|
| Section A ( Qa) | 0.04 | 1.2594 | 2.17 | 0.580369 | 21.91 | 0.98 | 0.78 | 0.59 |
| Section B ( Qb) | 0.04 | 17.2943 | 8.201 | 2.108907 | 711.02 | 31.80 | 1.84 | 107.49 |
| Section C ( Qc) | 0.04 | 1.38 | 3.0926 | 0.446226 | 73.23 | 3.28 | 2.37 | 18.45 |
| | | **19.9337** | | | **806.16** | **36.05** | | **126.53** |

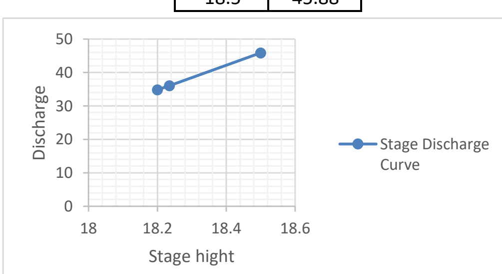
Stage Ht 18.50

| Sub Section | Manningss Coefficient n | a, Area ( m2) | p , Weted Perimeter (m) | m= a/p | $k = am^{2/3}/n$ | $q=kS_0^{1/2}$ | v=q/a | $qv^2$ |
|---|---|---|---|---|---|---|---|---|
| 0.959 | 0.04 | 1.7707 | 2.6074 | 0.679106 | 34.20 | 1.53 | 0.86 | 1.14 |
| Section B ( Qb) | 0.04 | 19.2678 | 8.285 | 2.325625 | 845.54 | 37.81 | 1.96 | 145.64 |
| Section C ( Qc) | 0.04 | 2.2416 | 4.2095 | 0.53251 | 146.10 | 6.53 | 2.91 | 55.51 |
| | | 23.2801 | | | 1025.84 | 45.88 | | 202.29 |

| Stage ht | Q |
|---|---|
| 18.2 | 34.83318 |
| 18.235 | 36.05 |
| 18.5 | 45.88 |

**Flood Stage Level**

18.23



| | | | | | | |
|---|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | | |
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

| | | |
|---|---|---|
| Flood Stage Level | **18.24** | msl |
| Width at Flood Stage | 11.5932 | m |
| River Bed Level | 15.46 | msl |
| | | |
| Bridge Span | 7.3 | m |
| No of Piers | 0 | Nos |
| Pier Width Wp | 0 | m |
| Flow Approach Angle | 15 | degrees |

**Flow Type Determination**

Frode Number

$$Fr_n = [(\frac{Q^2 B}{g A_n^3})^{1/2}$$

0.44 <1

Flow is type 1 or type 2

**Specific Energy of unconstricted normal Flow**

$$y_n = \text{Flood stage level - river bed level}$$

2.78 m

$$V_n = \frac{Q}{A_n}$$

1.81 m/s

$$E_{sn} = y_n + \frac{V_n^2}{2g}$$

**2.94 m**

Calculate Specific energy of constrictied flow critical depth

$$y_{2c} = [(\frac{Q^2}{gb^2})^{1/3}$$

1.35 m

$$V_{2c} = \frac{Q}{y_{2c} b}$$

3.65 m/s

$$E_{sc} = y_{2c} + \frac{V_{2c}^2}{2g}$$

**2.03 m**

Calculate bridge opening ratio

$$M = \frac{Q_b}{Q}$$

0.88

Calculate Velocity Head Co efficient

$$\alpha_1 = \frac{\Sigma(qv^2)}{Q\ V_n^2}$$

1.07

| | | | | | | |
|---|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | | |
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

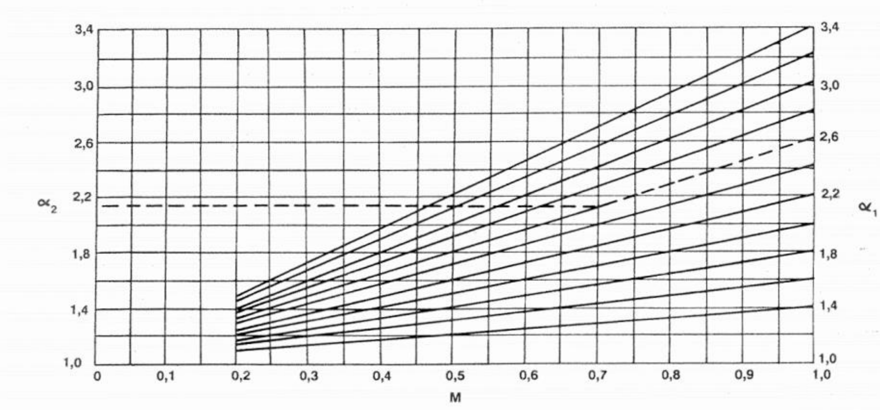
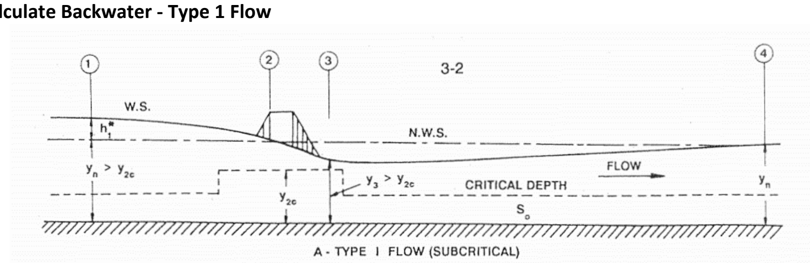



FIGURE 3.5 : VELOCITY HEAD COEFFICIENT IN CONSTRUCTION
(BUREAU OF PUBLIC ROADS, 1970)

$\alpha_2$ = **1.1**

**Calculate Backwater - Type 1 Flow**




**Pier Effect**

Projected area of the pier

$$A_p = N_p \bar{y} W_p = N_p \frac{A_{n2}}{b} W_p$$

**0.00** m2

$$J = \frac{A_p}{A_{n2}}$$

0

Eccentricity

$$e = 1 - \frac{Q_a}{Q_c}$$

**0.700862** check for Qc>QA othervise QC/Q

| | | | | | | |
|---|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | | |
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

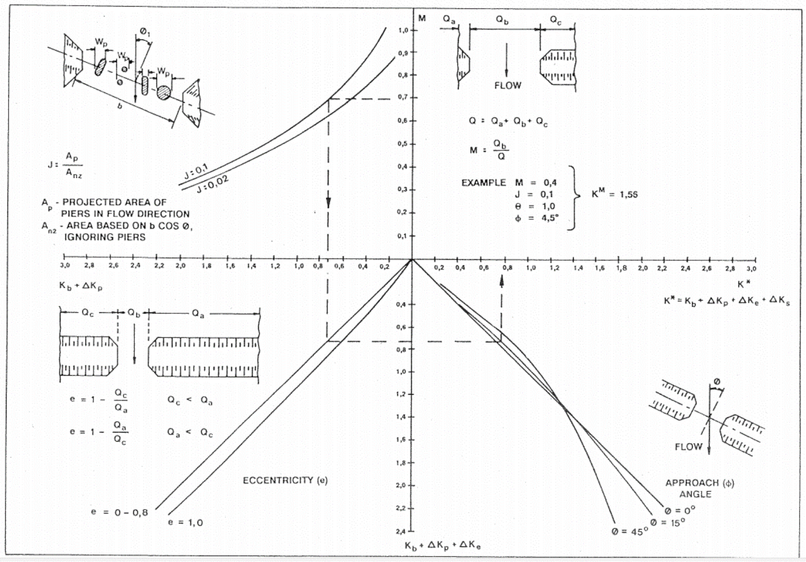



FIGURE 3.3 : CHART TO DETERMINE BACKWATER COEFFICIENT K* (BASED ON BUREAU OF PUBLIC ROADS, 1970 AND PUBLISHED IN NTC MANUAL ROOSEBOOM ET AL. 1981)

| | | |
|---|---|---|
| | M | 0.88 |
| | J | 0 |
| | e | 0.70 |
| Apprach Anges | shy | **15** |
| | $K^*$ | **0.27** |

Approximate Backwater

| | |
|---|---|
| An2 | 17.80 |

$$V_{n2} = \frac{Q}{A_{n2}}$$

2.03 m/s

$$h_1^{*1} = K^* \alpha_2 \frac{V_{n2}^2}{2g}$$

0.06 m

$$A_1 = A_n + h_1^{*1} B$$

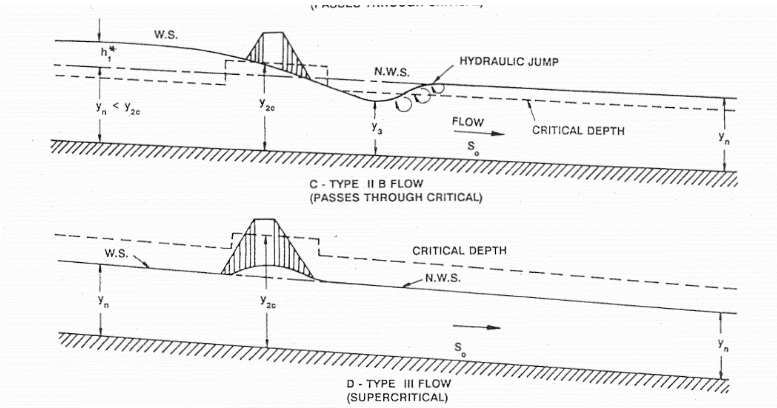
20.65363 m2

$$h_1^* = h_1^{*1} + \alpha_1 \left[\left(\frac{A_{n2}}{A_4}\right)^2 - \left(\frac{A_{n2}}{A_1}\right)^2\right] \frac{V_{n2}^2}{2g} \quad (Eqn.\ 3.1)$$

**0.07 m**

| | | | | | | |
|---|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | | |
| Bridge No | Strade River | Designed | YS | | | |
| Place | Mayo | Checked | MG | | | |

**Calculate Backwater - Type ii Flow**




$$b_c = (b - \Sigma W_p)$$

7.3 m

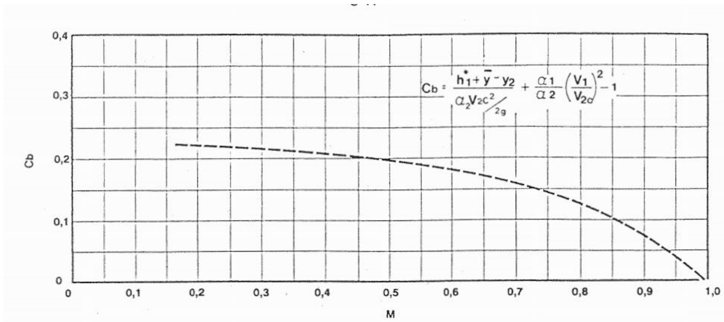



FIGURE 3.8 : DISCHARGE COEFFICIENT FOR TYPE II FLOW
(BUREAU OF PUBLIC ROADS, 1970)

Cb **0.08**

$$y_{2c} = \left(\frac{Q^2}{gb_c^{\,2}}\right)^{1/3}$$

1.35

$$y = \frac{A_{n2}}{b}$$

2.44 m

| | | | | | |
|---|---|---|---|---|---|
| Project | Mayo Bridges | Date | ######## | | |
| Bridge No | Strade River | Designed | YS | | |
| Place | Mayo | Checked | MG | | |

$$V_1 = \frac{Q}{A_n}$$

1.81 m/s

$$V_{2c} = (g.y_{2c})^{0,5}$$

3.65 m/s

$$h_1^* = \alpha_2 \frac{V_{2c}^2}{2g}(C_b + 1) - \alpha_1 \frac{V_1^2}{2g} + y_{2c} - \bar{y}$$

0.804708 0.178882 1.35 2.78

-0.794

$$A_1 = A_n + h_1^* B$$

10.72351 m2

V1 3.36 m/s

$$h_1^* = \alpha_2 \frac{V_{2c}^2}{2g}(C_b + 1) - \alpha_1 \frac{V_1^2}{2g} + y_{2c} - \bar{y}$$

0.804708 0.618113 1.35 2.78

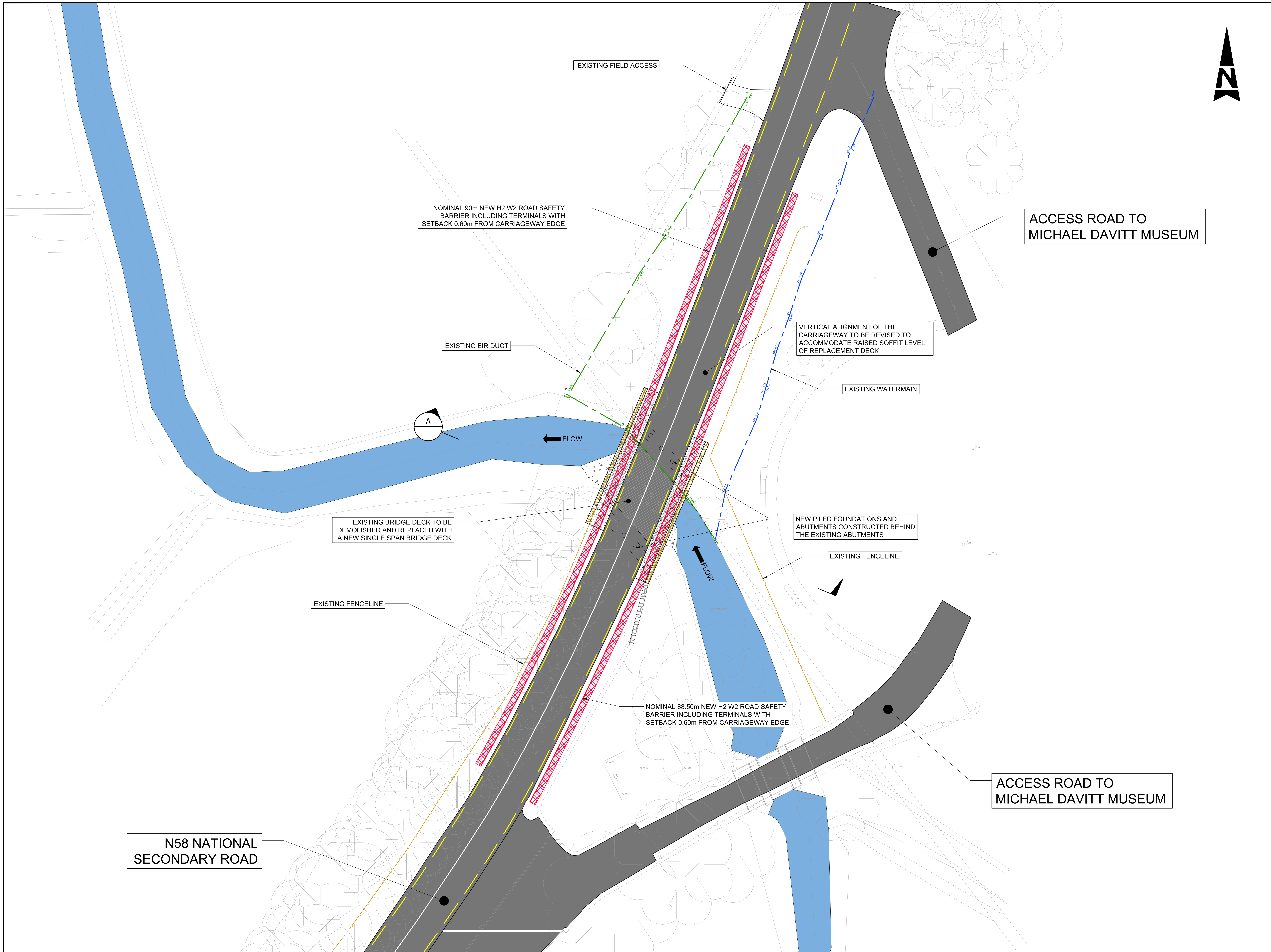
**h1** **-1.23**

| | |
|---|---|
| Stage height Normal Water Level | 18.24 |
| Backwater height | 0.07 |
| High flood level for Design Discharge | 18.31 |
| Bridge Soffit | 18.32 |
| Free board | **0.01** |

# Appendix D. Drawings

A1

DO NOT SCALE




GENERAL NOTES

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5. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION

DRAWING NOTES

1. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH 0088572DG0046 - Strade River Bridge Options Report



| Risk Level | | |
|---|---|---|
| | X | Atkins Base Line - Low Risk |
| | | Atkins Sensitive - Medium Risk |
| | | Atkins Private - High Risk |
| | | Client Critical - Already Marked |

| Rev | Description | By | Date | Chk'd | Rev'd | Auth |
|---|---|---|---|---|---|---|
| P01 | REVIEW COMMENTS INCORPORATED | AOS | 03.25 | MG | MJ | MJ |
| P0 | ISSUED FOR REVIEW | AGL | 01.25 | MG | MJ | MJ |


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Client: Comhairle Contae Mhaigh Eo / Mayo County Council

Project: TO315 - MAYO BRIDGE ASSESSMENTS AND STRENGTHENING 2023

Purpose: PRELIMINARY ISSUE

Title: Strade River Bridge
MO-N58-001.00
Proposed Site Layout Plan

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:250 | AGL | MG | MJ | MJ |
| | Date 03.01.25 | Date 03.01.25 | Date 03.01.25 | Date 03.01.25 |

| Status | Drawing Number | Rev |
|---|---|---|
| S0 | 0088572-ATK-02-XX-DR-CE-900203 | P01 |

File: 0088572-ATK-02-XX-DR-CE-900203 to 900207.dwg Date: Mar 25, 2025 - 11:46am Plotted by: OSUL1190

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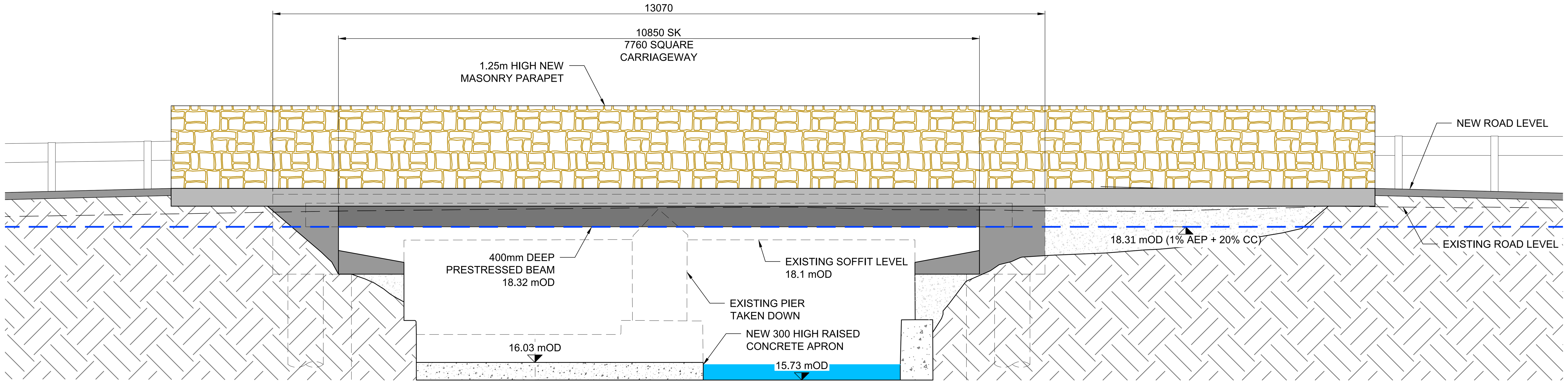
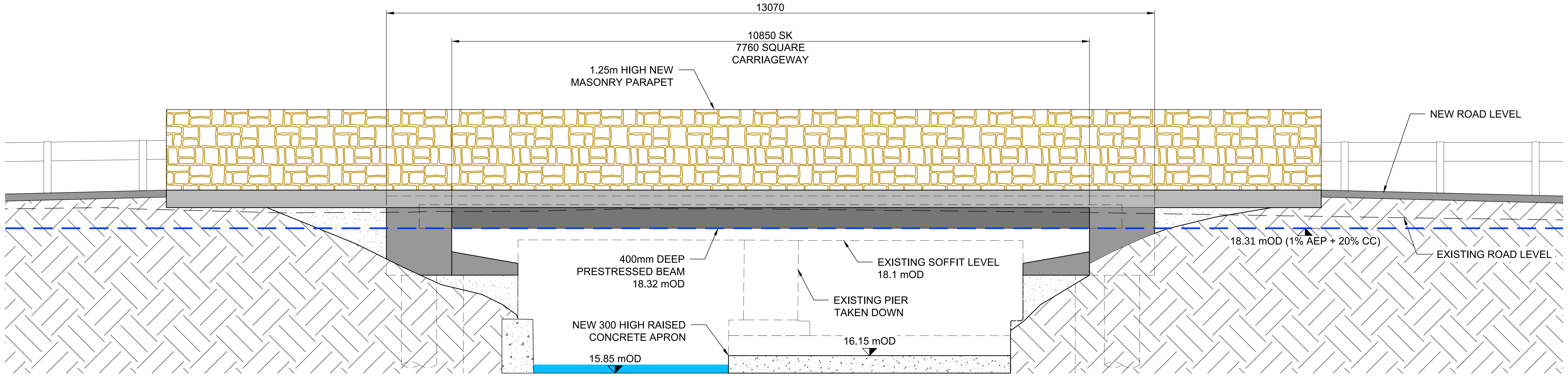
A1

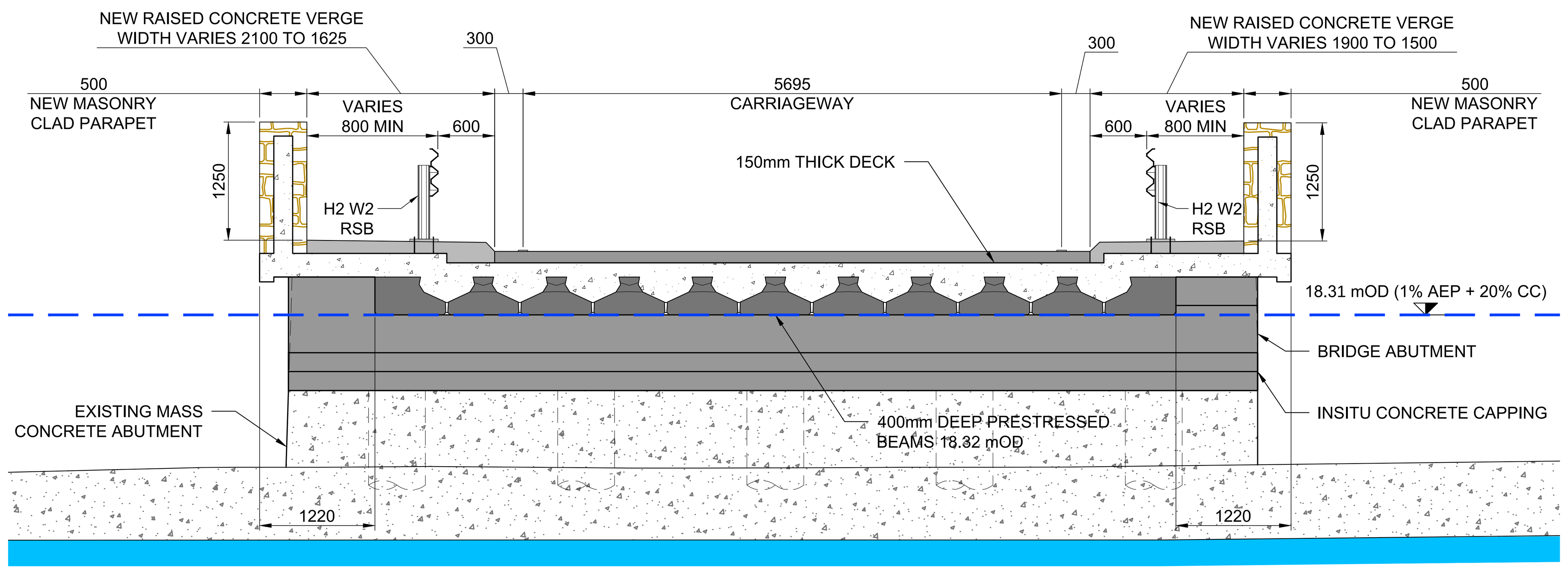
DO NOT SCALE




## EAST ELEVATION
Scale at A1 1:50
Scale at A3 1:100




## WEST ELEVATION
Scale at A1 1:50
Scale at A3 1:100




## SECTION A
Scale at A1 1:50

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DRAWING NOTES

1. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH 0088572DG0046 - Strade River Bridge Options Report



| Risk Level | | |
|---|---|---|
| | X | Atkins Base Line - Low Risk |
| | | Atkins Sensitive - Medium Risk |
| | | Atkins Private - High Risk |
| | | Client Critical - Already Marked |

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Oifig Deartha Náisiúnta Dhún na nGall

| Rev | Description | By | Date | Chk'd | Rev'd | Auth |
|---|---|---|---|---|---|---|
| P01 | REVIEW COMMENTS INCORPORATED | AOS | 03.25 | MG | MJ | MJ |
| P0 | ISSUED FOR REVIEW | AGL | 01.25 | MG | MJ | MJ |

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Client: Comhairle Contae Mhaigh Eo Mayo County Council

Project: TO315 - MAYO BRIDGE ASSESSMENTS AND STRENGTHENING 2023

Purpose: PRELIMINARY ISSUE

Title: Strade River Bridge
MO-N58-001.00
Proposed Elevations & Section

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:50 | AGL Date 03.01.25 | MG Date 03.01.25 | MJ Date 03.01.25 | MJ Date 03.01.25 |

| Status | Drawing Number | Rev |
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A1

DO NOT SCALE

0 10 100

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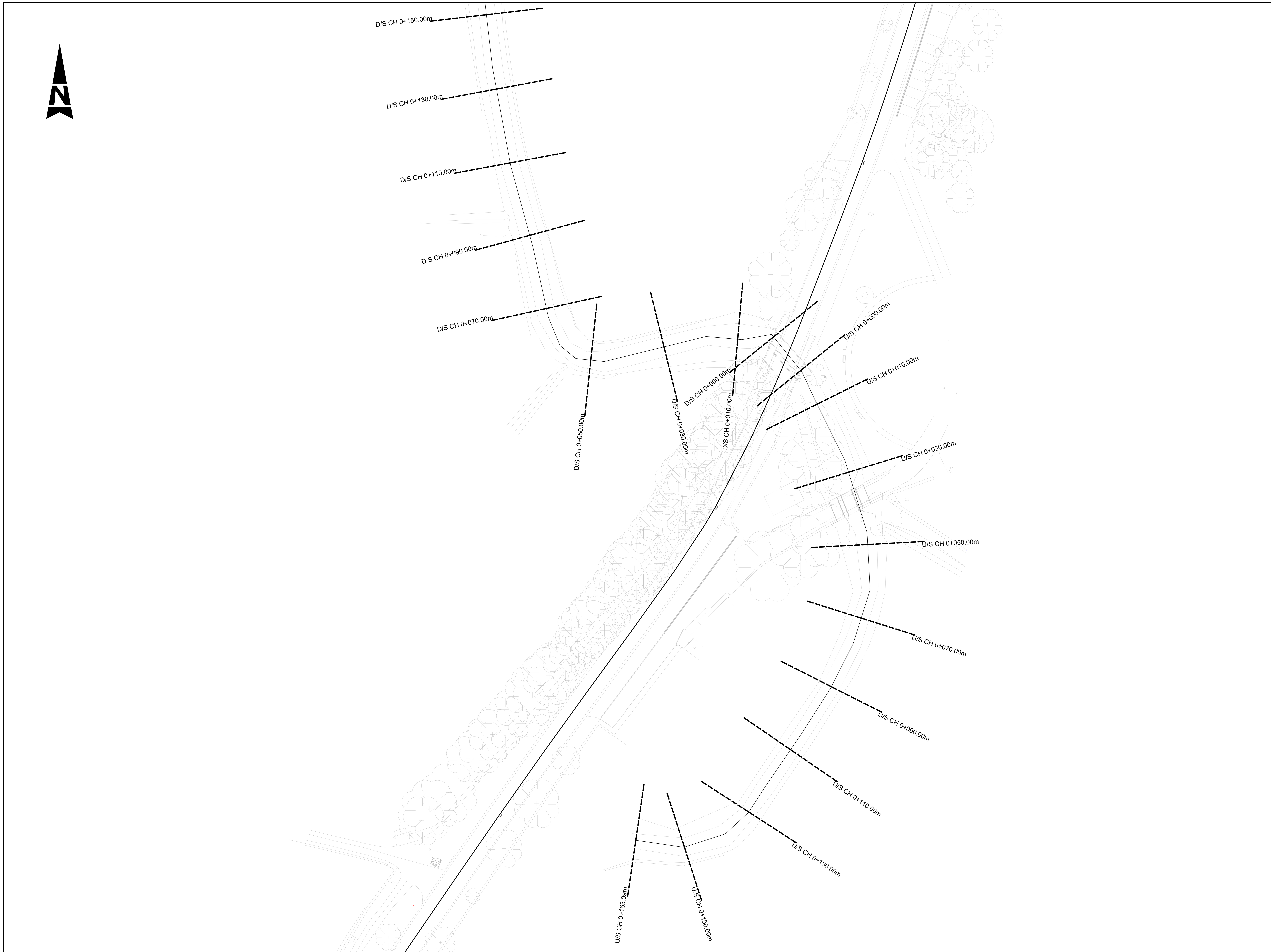


GENERAL NOTES

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| Risk Level | | |
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| P0 | ISSUED FOR REVIEW | AGL | 12.24 | MG | MG | MJ |

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Client: Comhairle Contae Mhaigh Eo / Mayo County Council

Project: STRADE RIVER BRIDGE PEDESTRIAN IMPROVEMENTS SCHEME

Purpose: PRELIMINARY ISSUE

Title: OPW SECTION 50 APPLICATION PLAN

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:500 | AGL (Date 20.12.24) | MG (Date 03.12.24) | MG (Date 20.12.24) | MJ (Date 20.12.24) |

| Status | Drawing Number | Rev |
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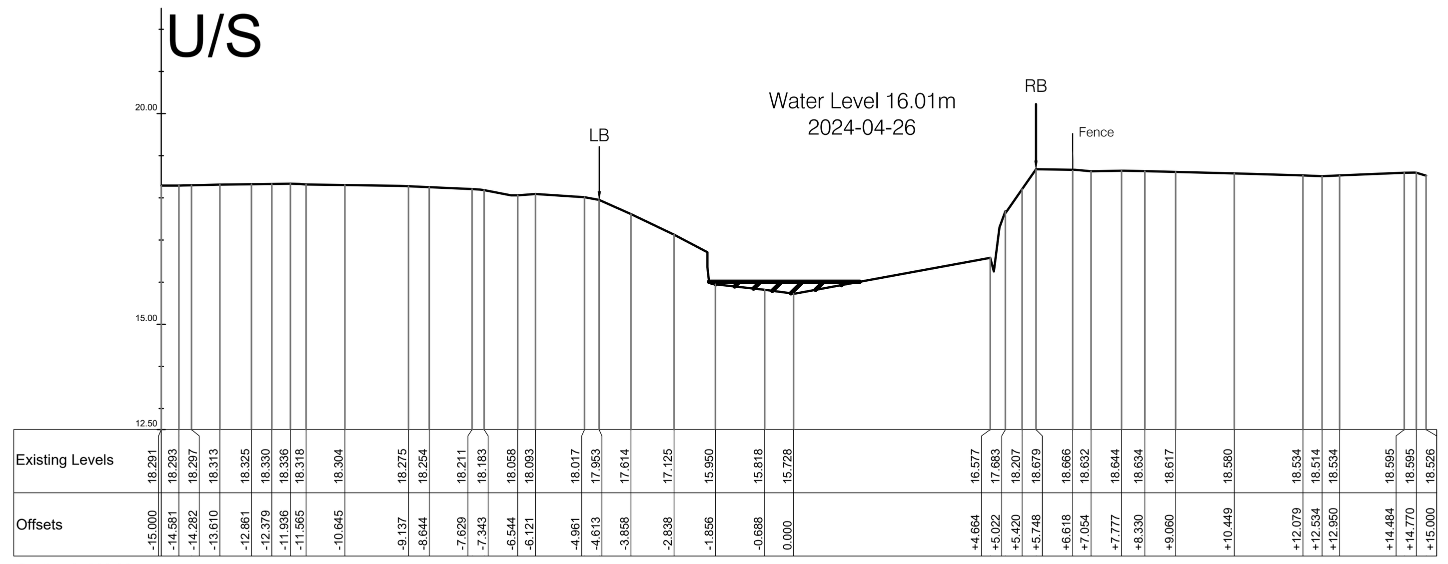


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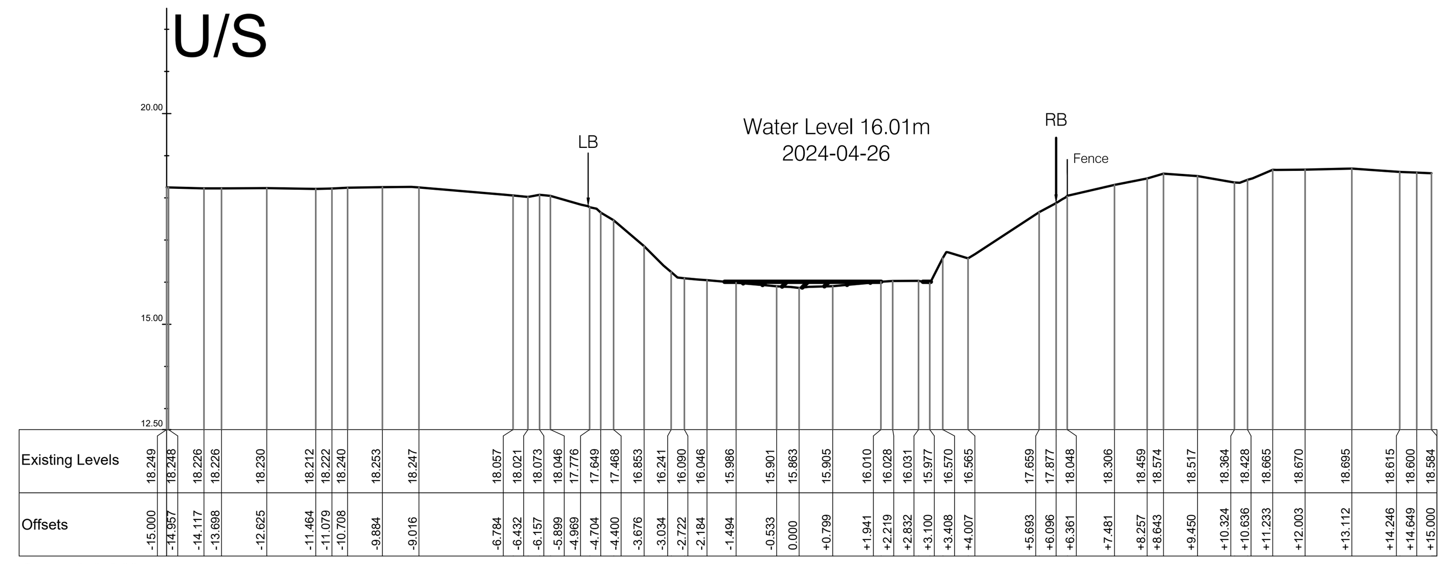


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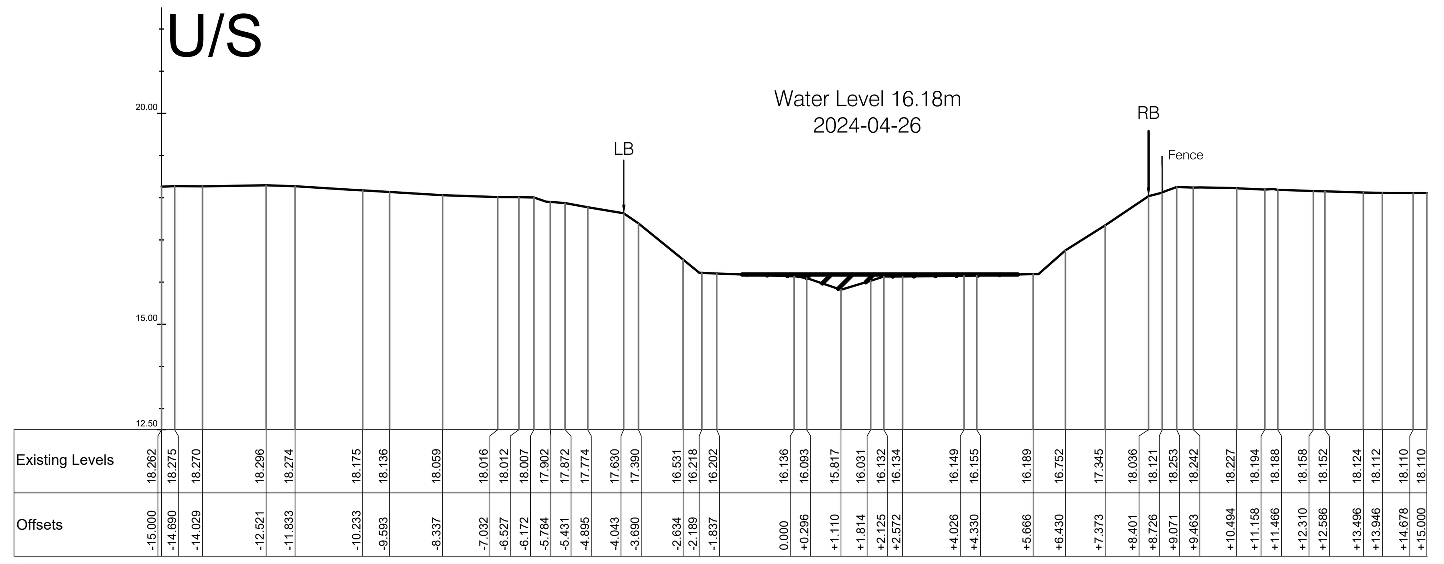


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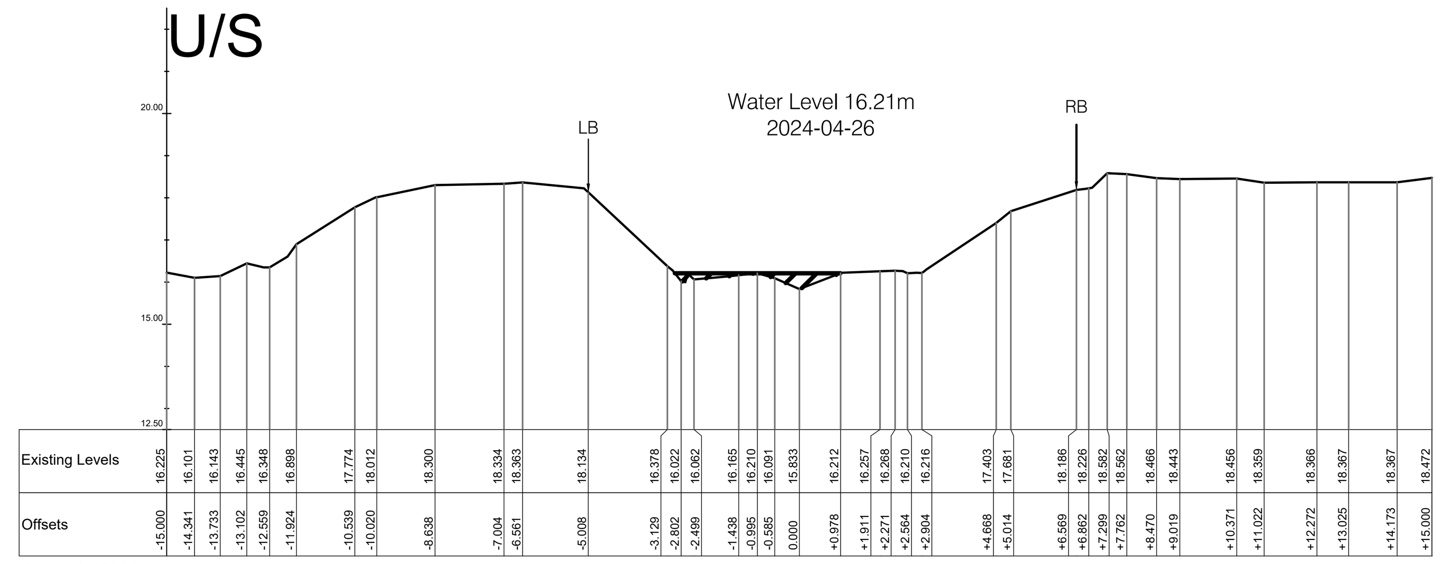


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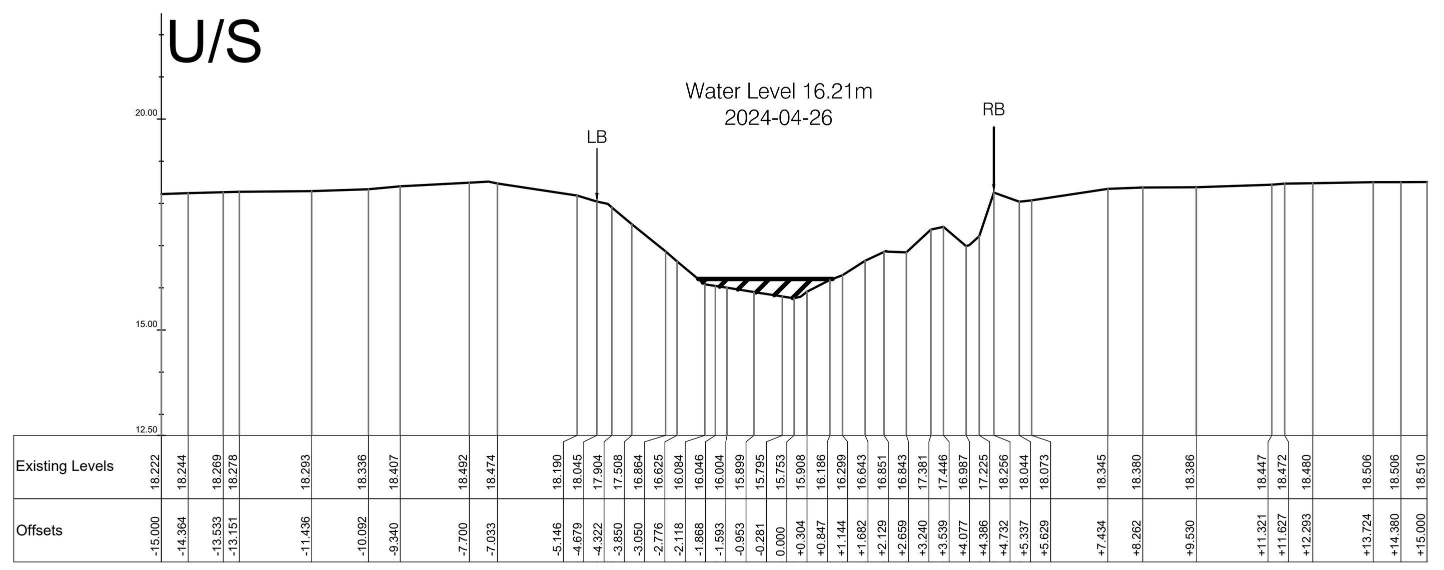


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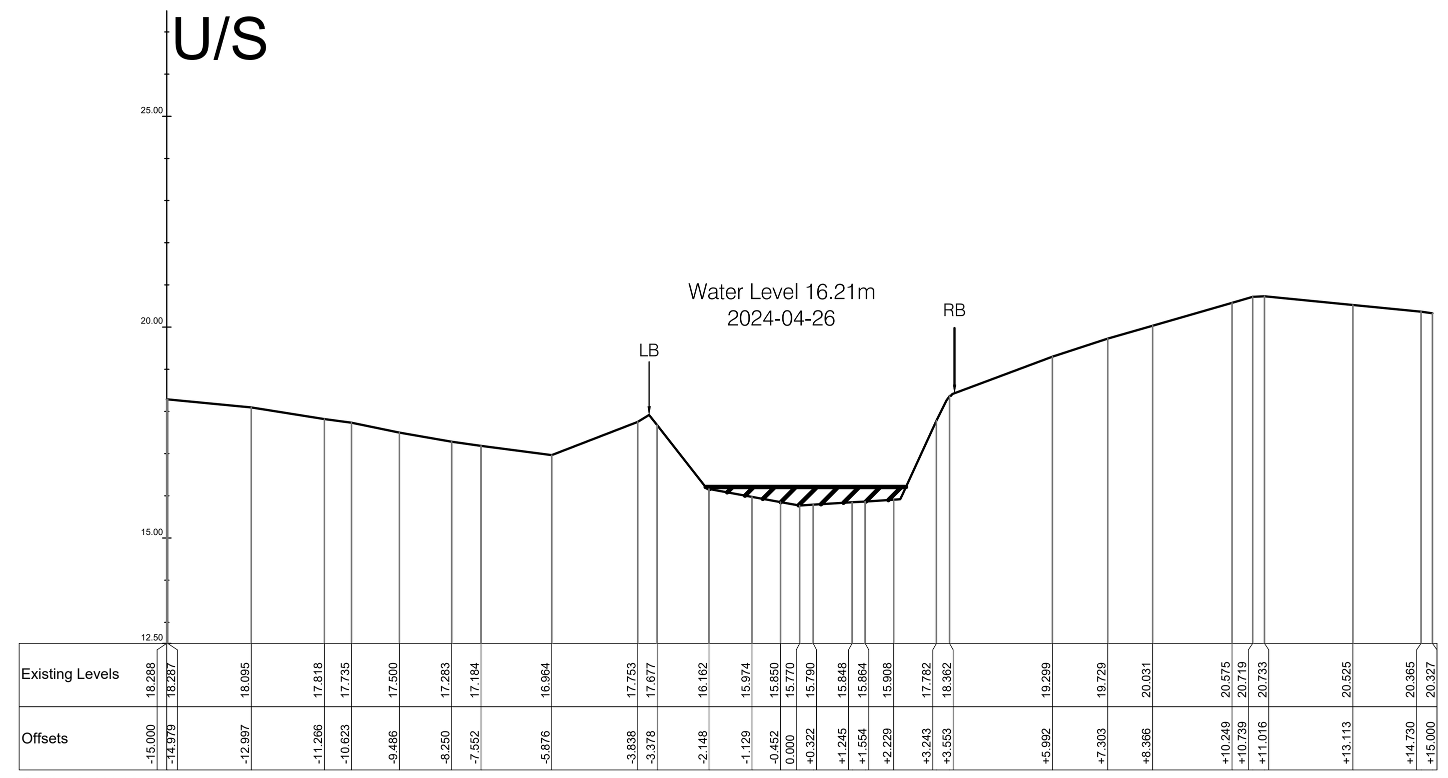


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Project: STRADE RIVER BRIDGE PEDESTRIAN IMPROVEMENTS SCHEME

Purpose: PRELIMINARY ISSUE

Title: OPW SECTION 50 APPLICATION RIVER CROSS SECTIONS SHEET 1 OF 4

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:150 | AGL | MG | MG | MJ |
| | Date 20.12.24 | Date 2012.24 | Date 20.12.24 | Date 20.12.24 |

| Status | Drawing Number | Rev |
|---|---|---|
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Date: Jan 03, 2025 - 1:22pm

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A1

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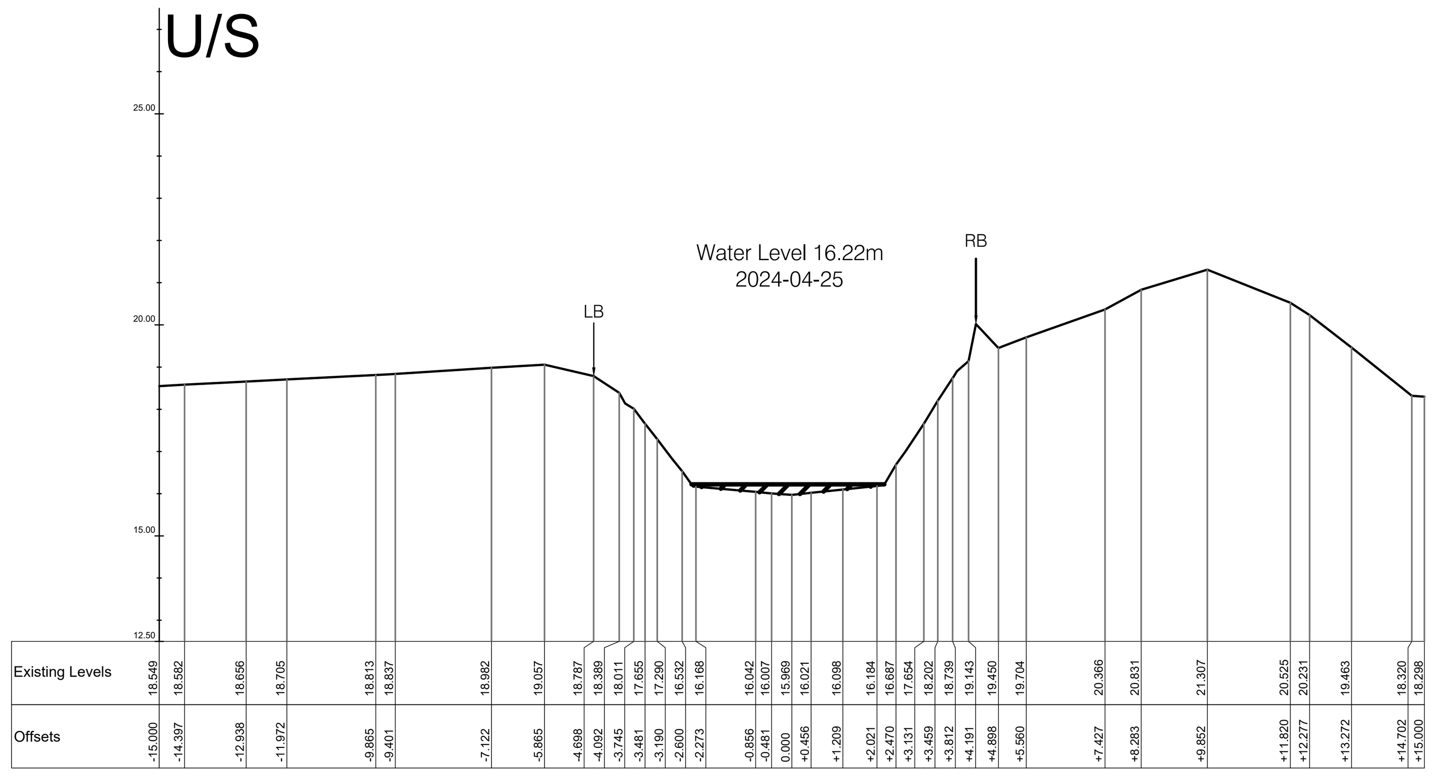
Date: Jan 03, 2025 - 1:22pm

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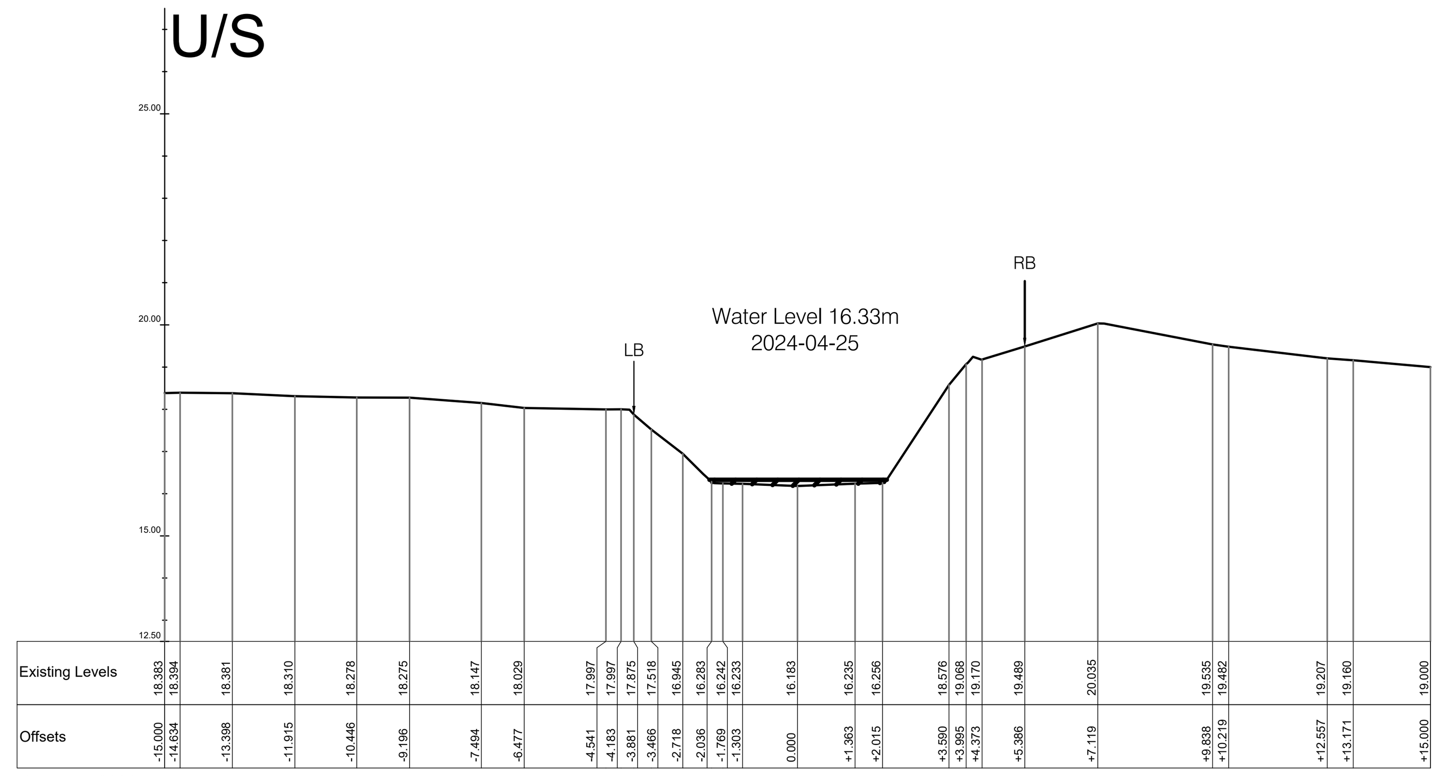


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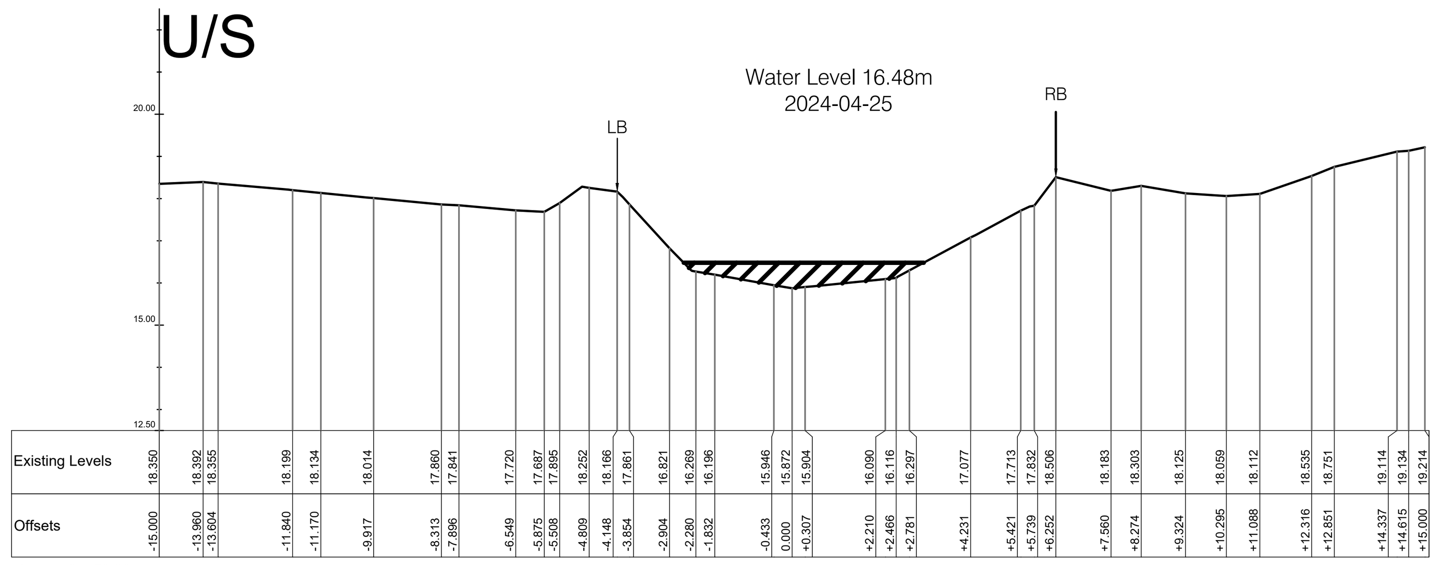


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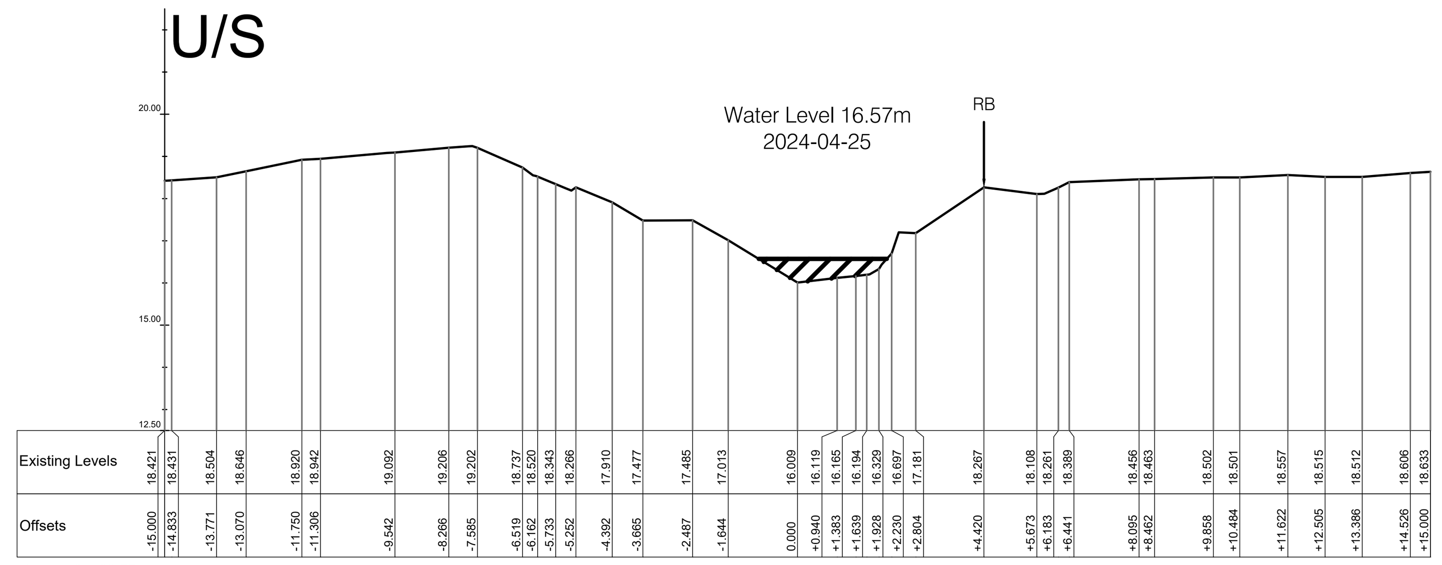


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Datum: 12.50

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| | | Client Critical - Already Marked |

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Client: Comhairle Contae Mhaigh Eo / Mayo County Council

Project: STRADE RIVER BRIDGE PEDESTRIAN IMPROVEMENTS SCHEME

Purpose: PRELIMINARY ISSUE

Title: OPW SECTION 50 APPLICATION RIVER CROSS SECTIONS SHEET 2 OF 4

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:150 | AGL<br>Date 20.12.24 | MG<br>Date 20.12.24 | MG<br>Date 20.12.24 | MJ<br>Date 20.12.24 |

| Status | Drawing Number | Rev |
|---|---|---|
| S0 | 0088572-ATK-02-XX-DR-CE-900122 | P0 |

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A1

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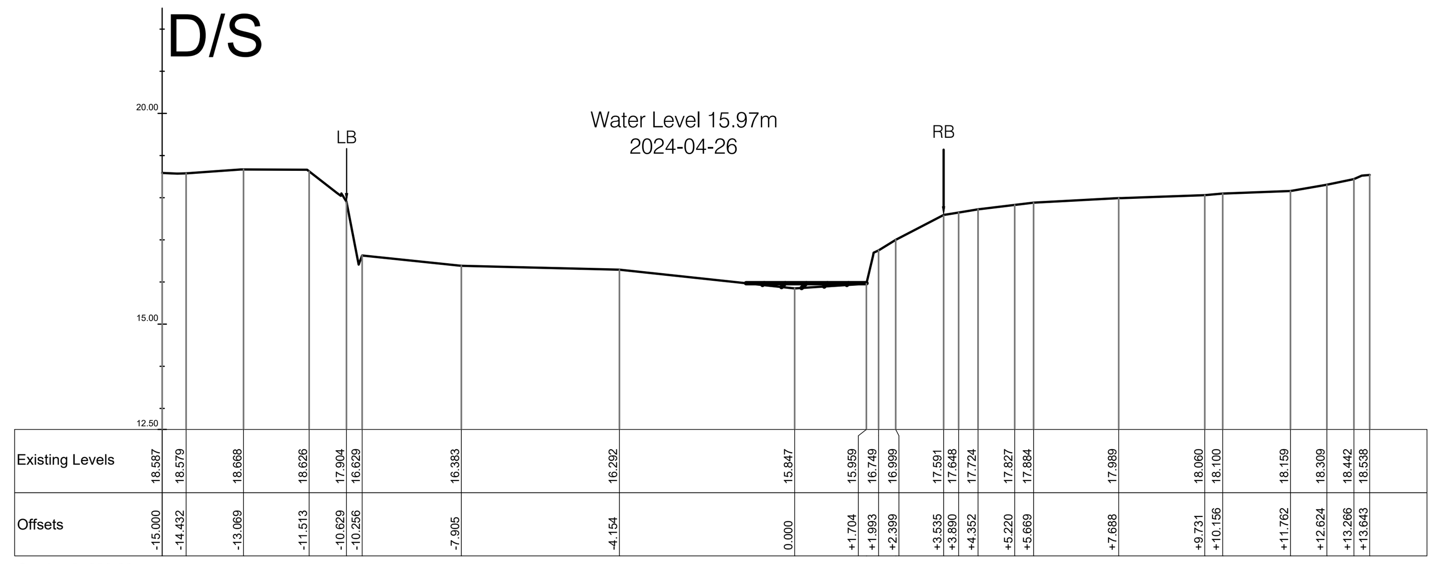


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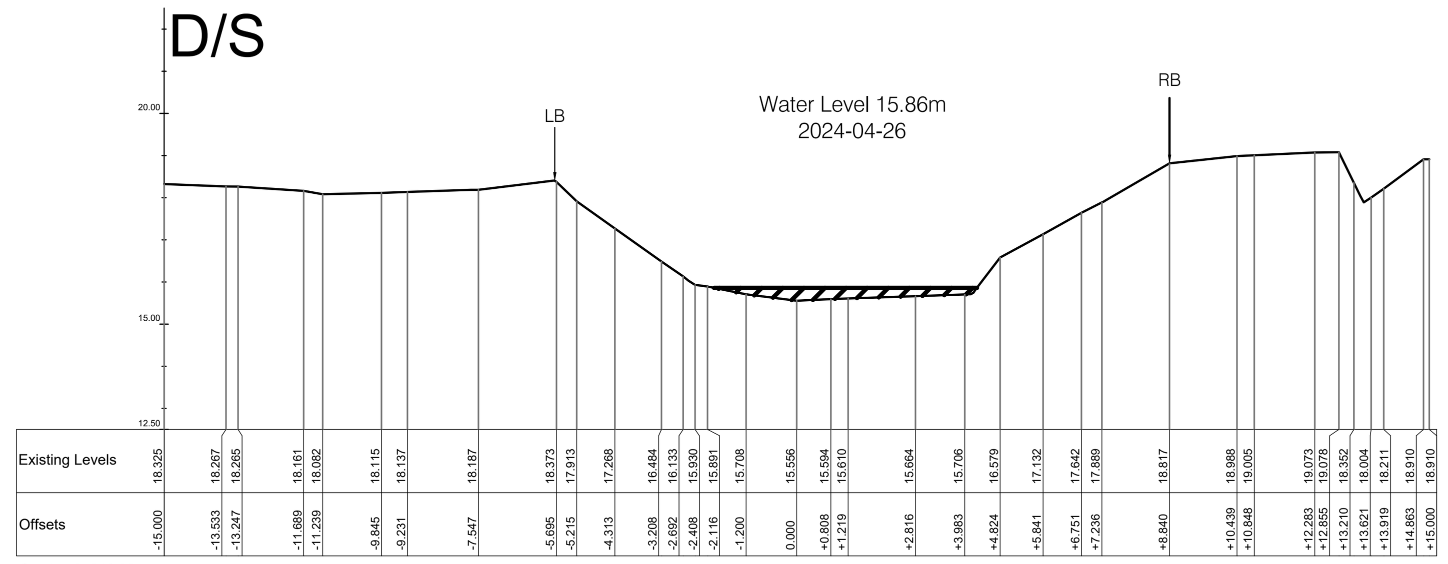


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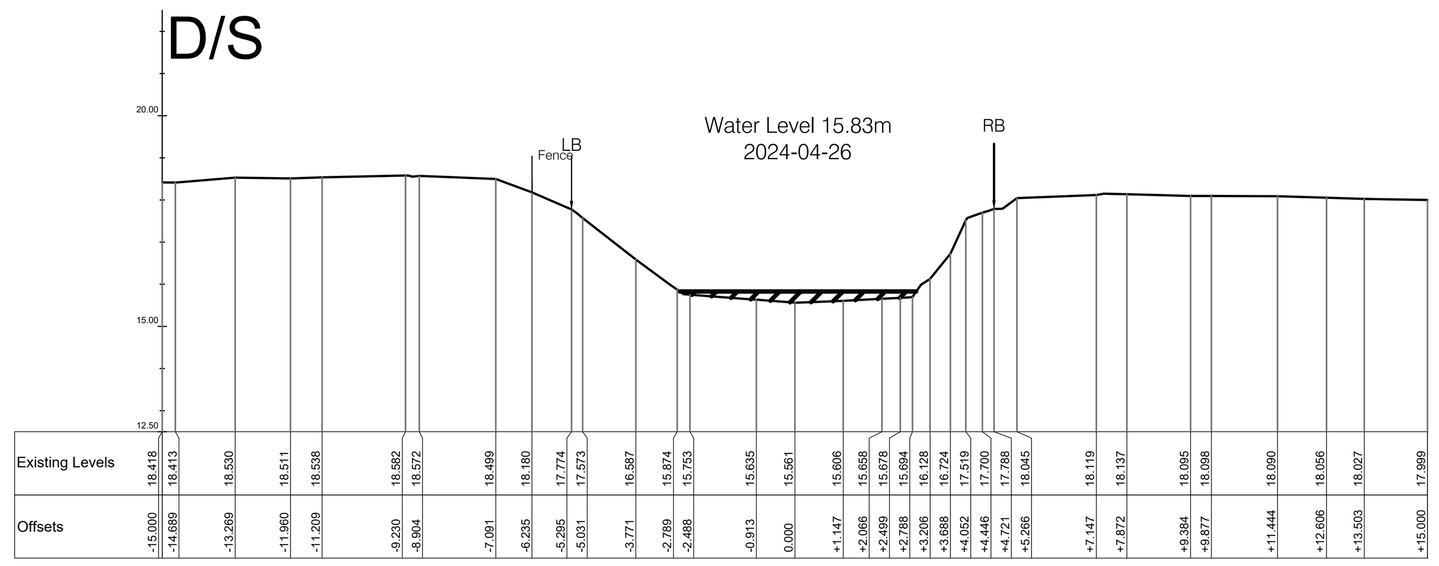


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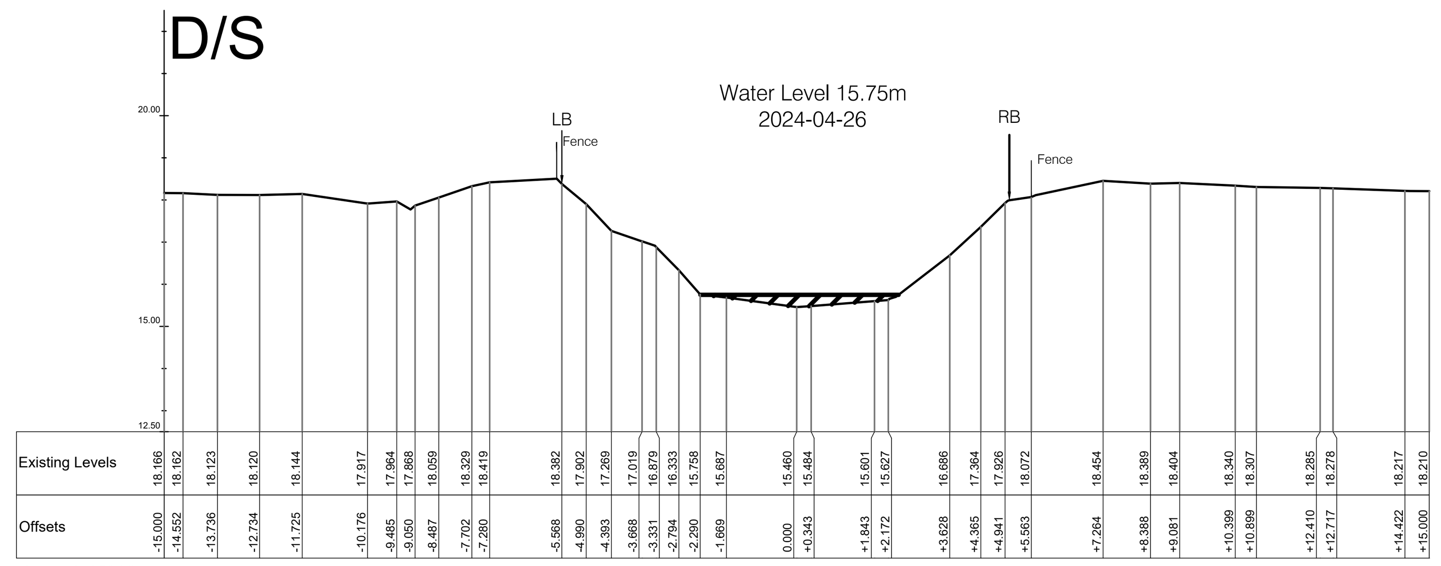


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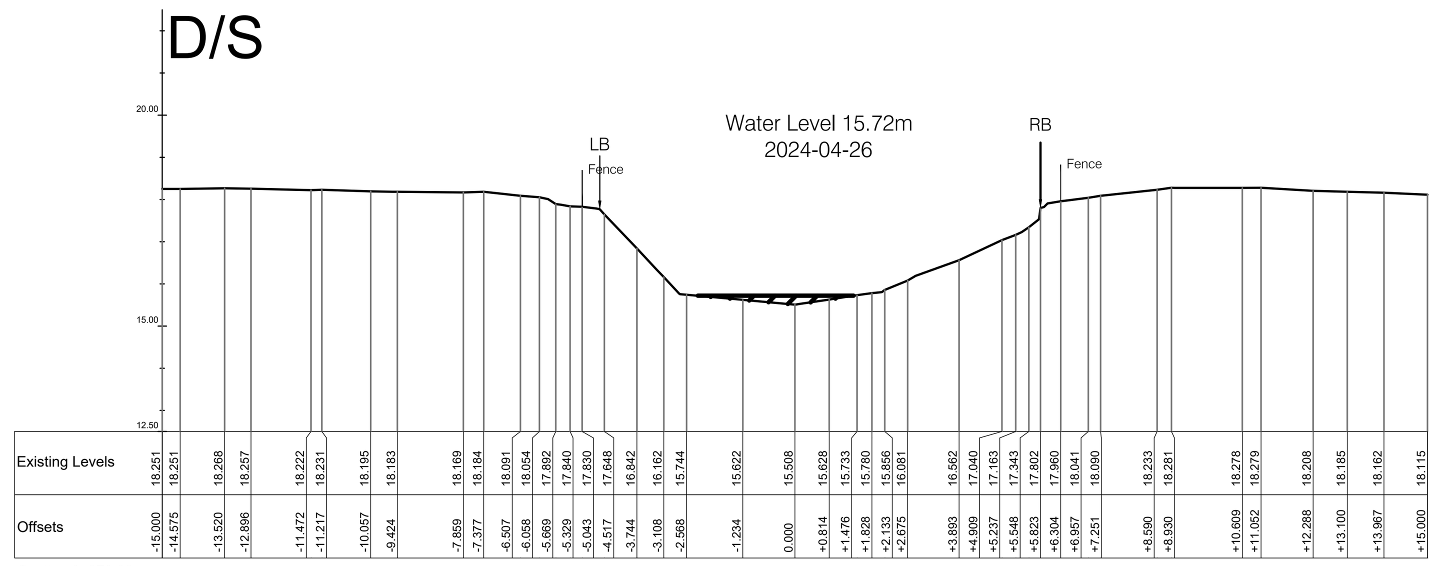


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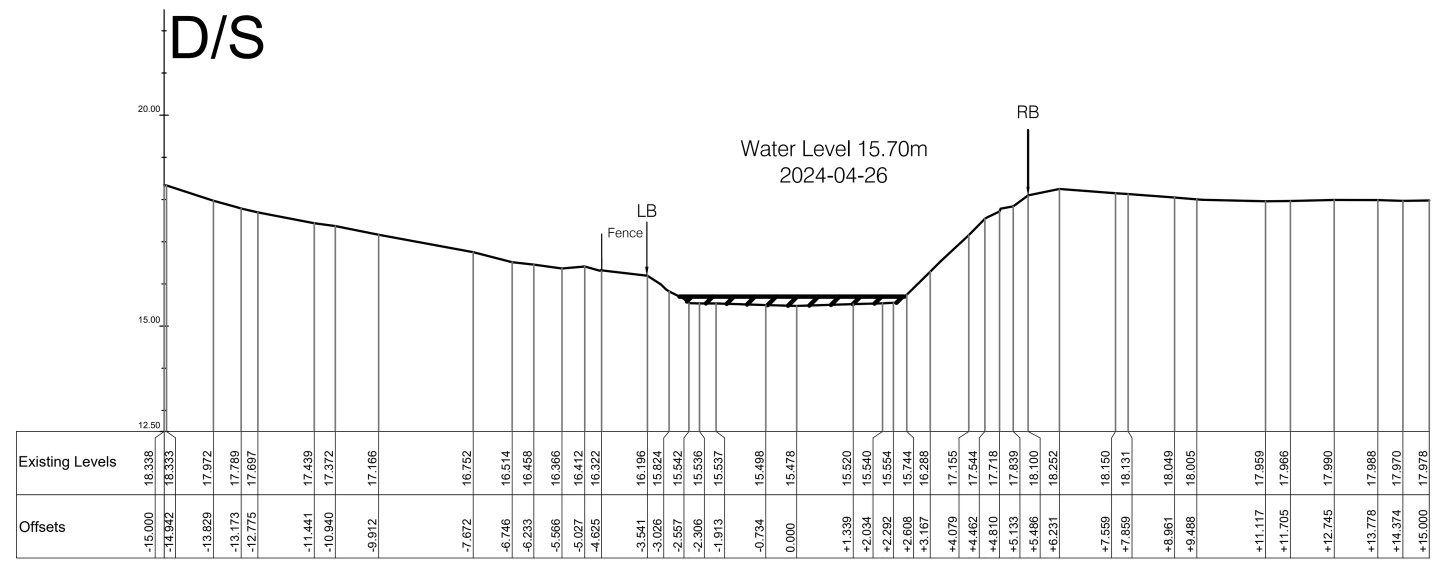
Vertical Scale: 100.000
Datum: 12.50




Section 0+090.00
Horizontal Scale: 100.000
Vertical Scale: 100.000
Datum: 12.50



| Risk Level | | |
|---|---|---|
| | X | Atkins Base Line - Low Risk |
| | | Atkins Sensitive - Medium Risk |
| | | Atkins Private - High Risk |
| | | Client Critical - Already Marked |

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Comhairle Contae Mhaigh Eo
Mayo County Council

| Rev | Description | By | Date | Chk'd | Rev'd | Auth |
|---|---|---|---|---|---|---|
| P0 | ISSUED FOR REVIEW | AGL | 12.24 | MG | MG | MJ |

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Client: Comhairle Contae Mhaigh Eo
Mayo County Council

Project: STRADE RIVER BRIDGE
PEDESTRIAN IMPROVEMENTS SCHEME

Purpose: PRELIMINARY ISSUE

Title: OPW SECTION 50 APPLICATION
RIVER CROSS SECTIONS
SHEET 3 OF 4

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:150 | AGL | MG | MG | MJ |
| | Date 20.12.24 | Date 20.12.24 | Date 20.12.24 | Date 20.12.24 |

| Status | Drawing Number | Rev |
|---|---|---|
| S0 | 0088572-ATK-02-XX-DR-CE-900123 | P0 |

File: 0088572-ATK-02-XX-DR-CE-900120 to 900125.dwg
Date: Jan 03, 2025 - 1:22pm Plotted by: alopez

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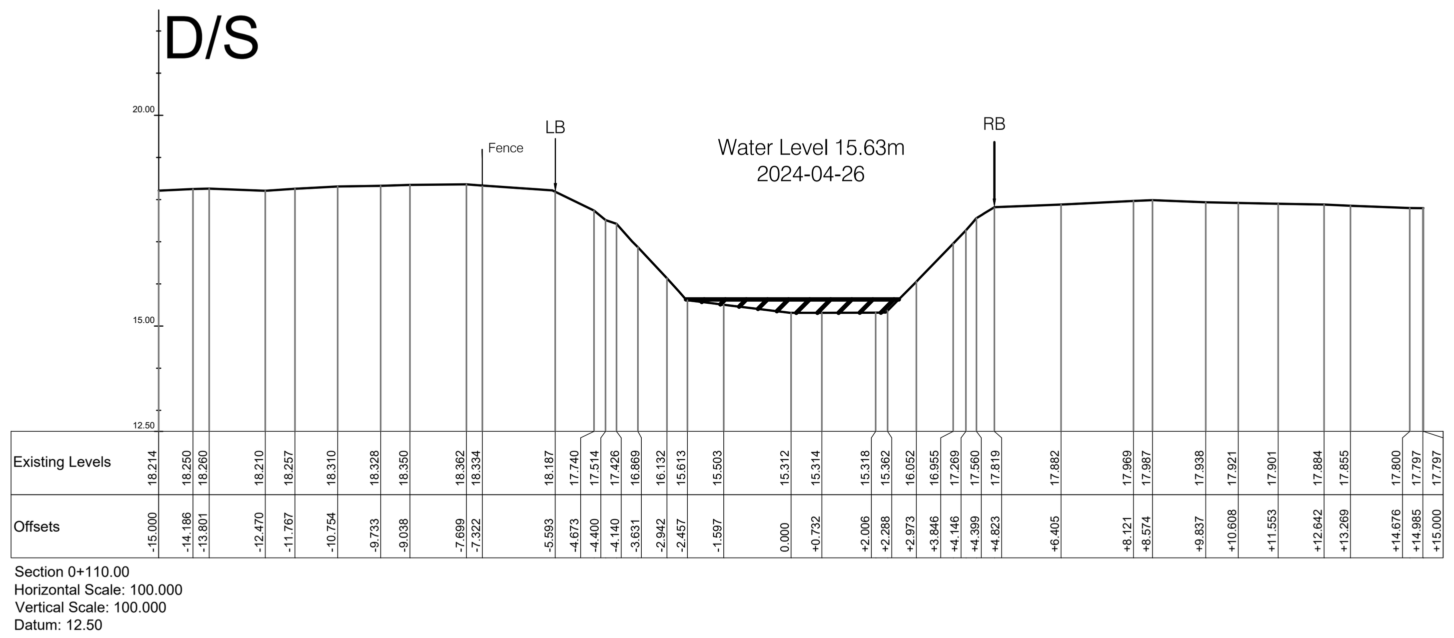
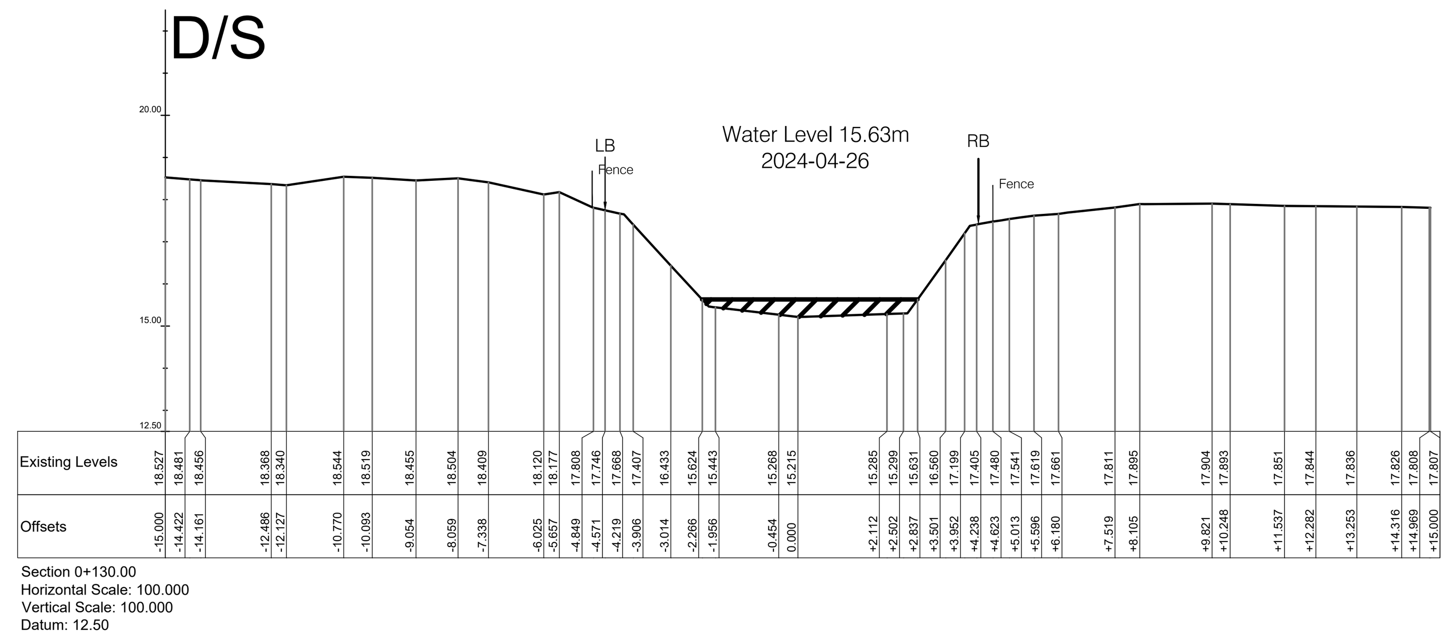
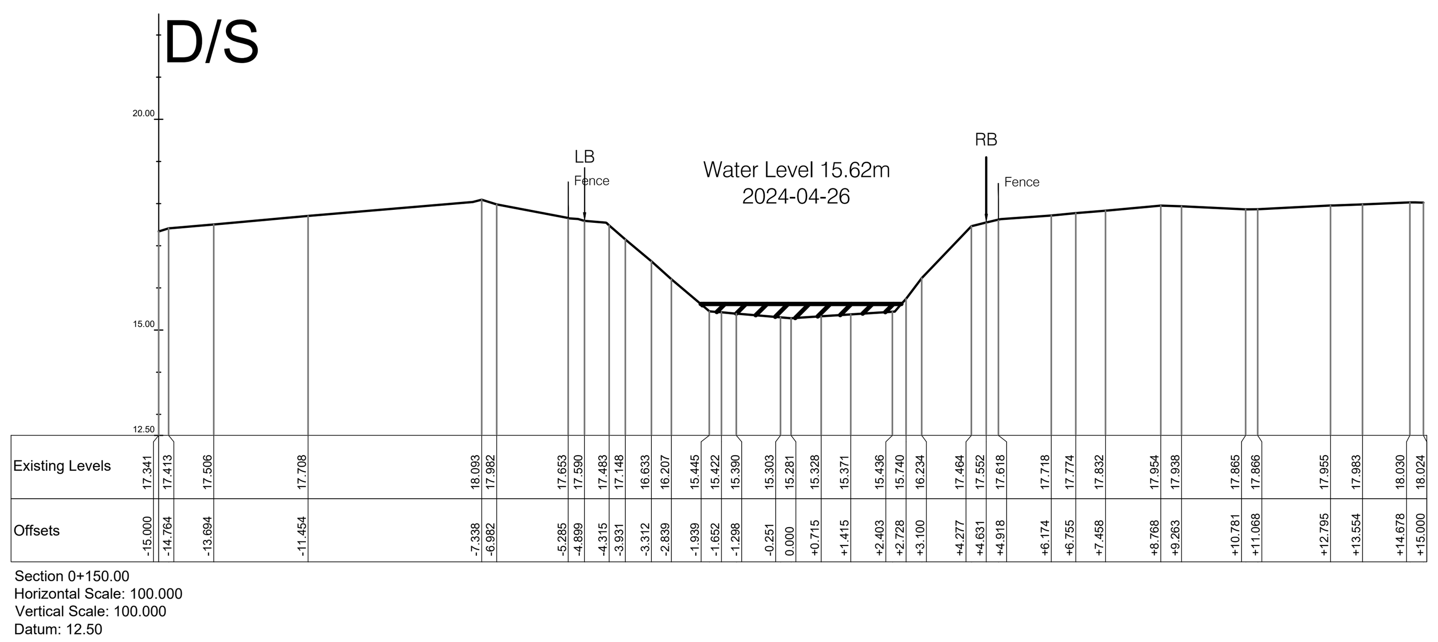
A1

DO NOT SCALE




GENERAL NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE
2. ONLY WRITTEN DIMENSIONS SHALL BE USED. NO DIMENSIONS SHALL BE SCALED FROM THE DRAWINGS
3. ALL LEVELS ARE IN METRES AND ARE TO MALIN HEAD DATUM
4. ALL COORDINATES ARE IN METRES AND ARE TO IRISH TRANSVERSE MERCATOR
5. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION



| Risk Level | | |
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Client: Comhairle Contae Mhaigh Eo Mayo County Council

Project: STRADE RIVER BRIDGE PEDESTRIAN IMPROVEMENTS SCHEME

Purpose: PRELIMINARY ISSUE

Title: OPW SECTION 50 APPLICATION RIVER CROSS SECTIONS SHEET 4 OF 4

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:150 | AGL | MG | MG | MJ |
| | Date 20.12.24 | Date 20.12.24 | Date 20.12.24 | Date 20.12.24 |

| Status | Drawing Number | Rev |
|---|---|---|
| S0 | 0088572-ATK-02-XX-DR-CE-900124 | P0 |

File: 0088572-ATK-02-XX-DR-CE-900120 to 900125.dwg Plotted by: alopez
Date: Jan 03, 2025 - 1:22pm

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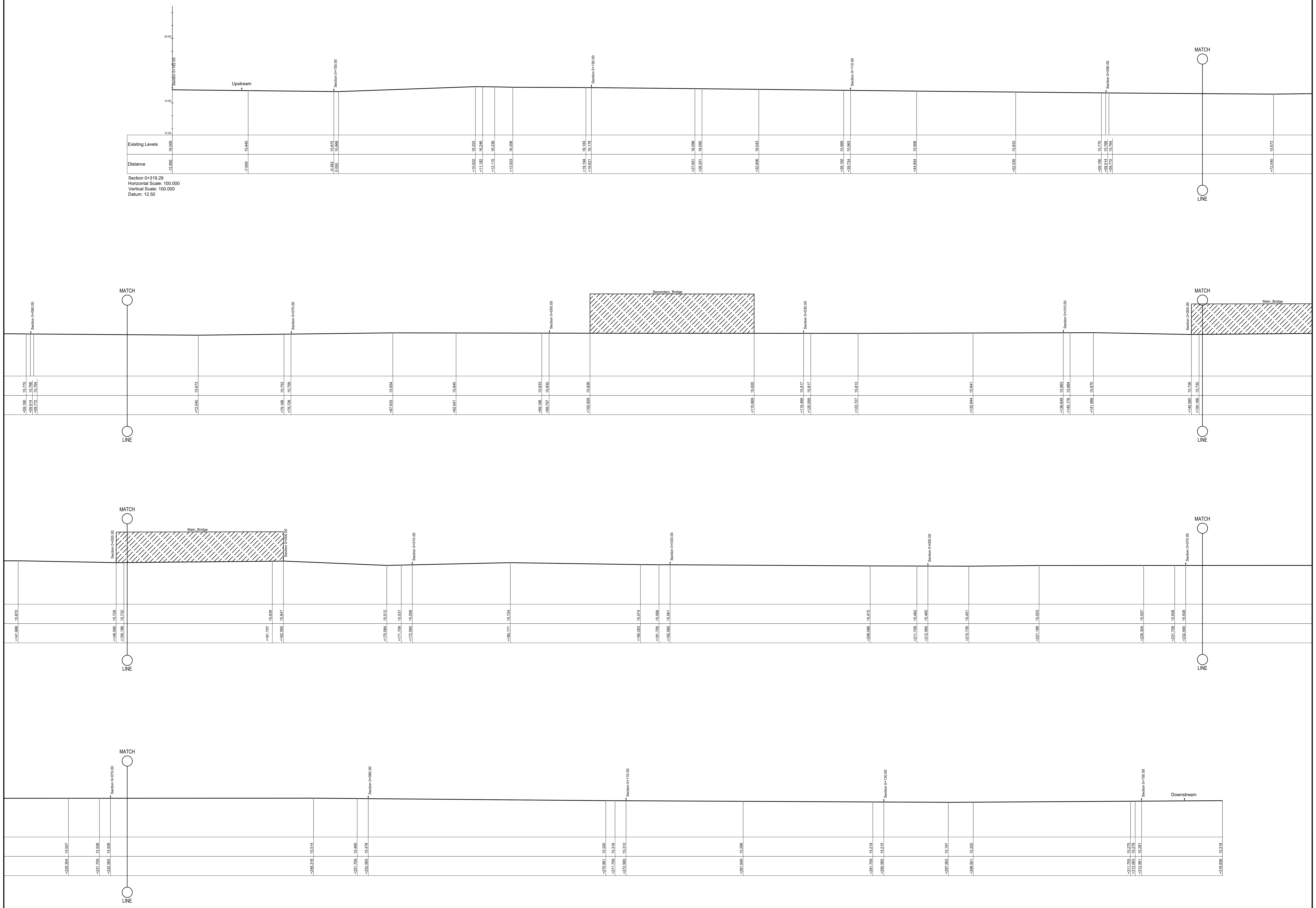
A1

DO NOT SCALE




## GENERAL NOTES

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| P0 | ISSUED FOR REVIEW | AGL | 12.24 | MG | MG | MJ |


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Client: Comhairle Contae Mhaigh Eo Mayo County Council

Project: STRADE RIVER BRIDGE PEDESTRIAN IMPROVEMENTS SCHEME

Purpose: PRELIMINARY ISSUE

Title: OPW SECTION 50 APPLICATION RIVER LONGITUDINAL SECTION

| Original Scale | Drawn | Checked | Reviewed | Authorised |
|---|---|---|---|---|
| 1:150 | AGL | MG | MG | MJ |
| | Date 20.12.24 | Date 20.12.24 | Date 20.12.24 | Date 20.12.24 |

| Status | Drawing Number | Rev |
|---|---|---|
| S0 | 0088572-ATK-02-XX-DR-CE-900125 | P0 |

File: 0088572-ATK-02-XX-DR-CE-900120 to 900125.dwg Plotted by: alopez
Date: Jan 03, 2025 - 1:22pm

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