Appendix 11.8

Arklow Bridge, Structural Report on Existing Masonry 19 Arch Bridge and advice Regarding Impacts of Proposed Flood Alleviation Scheme on Bridge

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Conservation Engineering Report
Arklow Bridge, Arklow, Co Wicklow

Conservation Engineering Report on existing Masonry 19 Arch bridge and advice regarding impacts of proposed Flood Alleviation Scheme on the bridge.

April 2021 **Project 18572** **Issue 4**

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Central pier of historic bridge over sailed by later bridge. *Photo c/o CourtneyDeery*

1 Introduction

1.1 Brief for Conservation Engineering Report

CORA Consulting Engineers were requested by Kieran Thornton of Byrne Looby to look at the impact of the various options for the grouting; underpinning and lowering of the riverbed on the 19 arch historic masonry bridge across the Avoca River at Arklow and advise on any repairs required to the historic masonry structure.

To gain an initial understanding of the overarching issues and project, the information in the public realm was consulted. The "Arklow Flood Relief Scheme Emerging Preferred Option - Public Consultation" leaflet summarises the need for flood protection and proposed works thus:

> *The objective of the proposed flood relief scheme at Arklow will be to protect the low lying areas of the town that are impacted during flood events from the Avoca River and the sea.*
> *The flood scheme will be designed to withstand a 1 in 100 year flood event from the Avoca River as well as 1 in 200 year tidal flooding. The flood defences will also be designed to withstand severe tidal events induced by severe weather conditions.*

Four options are outlined in that document with Option 4 being given as the preferred:

	Option 1	*Option 2*	*Option 3*	*Option 4*
Catchment Management	✓	✓	✓	✓
Channel and bank maintenance	✓	✓	✓	✓
Minor modifications to Arklow bridge	✓	✓	✓	✓
Sluice valves, non-return valves and pumping	✓	✓	✓	✓
Flood defence walls and embankments	✓	✓	✓	✓
Debris trap		✓		✓
Lowering of floor of Arklow Bridge by 1m,			✓	✓
Downstream widening on South Quay			✓	✓
Upstream and downstream extensive dredging			✓	✓

The items that are dealt with in this structural report are those shaded green.

The extent of works is described in chapter 4 of the EIAR thus:

These works which are referred as "Work Package 1 (WP1)" will include bridge underpinning of the bridge piers and southern abutment, remedial works to the older masonry parts of the bridge and lowering the floor of Arklow Bridge by approximately 1m, including removal of the existing scour protection slab and replacement with a new scour protection for the new river bed. Arklow Bridge is a protected structure (RPS A26). The significance of the protected structure status of the Bridge is addressed in Chapter 11 Archaeology, Architecture and Cultural Heritage.

The overall layout of all channel works is shown on Drawing No 1003 and the proposed bridge works are shown on Drawing Nos 1004 to 1010 inclusive in Appendix 4.1. These works are described further below.

also described in Chap 4 is the impact of the proposed flood protection & alleviation thus:

The proposed works aim to improve the flow capacity through the arches without disrupting the structural integrity of the bridge. The design proposes to reduce the floor of the bridge by 1.0m. This, together with the proposed dredging of the channel, is estimated to reduce the upstream flood level by 0.54m. Hence, the height of the flood defence walls and embankments required upstream of Arklow Bridge will be 0.54m lower than without the proposed works on the bridge.

More detail of the works to the bridge is described in chapter 4 thus:

The lowering of the floor of Arklow bridge will require the underpinning of the southern bridge abutment and the bridge piers from Arch 1 to 18.

Arch 1 will be reinstated at its current level to accommodate an interceptor sewer forming part of Arklow WwTP while Arch 19 will not be altered due to the services passing through this arch. An earlier historic apron to prevent scour is still existent in many places which takes the form of large interlocking stones. This will be lost when the riverbed is lowered in Arches 2 through to 18. Arch 1 will be reinstated to its current state reusing any existing stones which can be recovered in adequate condition i.e. largely undamaged. Any stones recovered in arches 2 to 18 will be incorporated into the proposed concrete scour slab. Arch 19 is to be retained as is, with its original interlocking stones retained.

The proposed grouting and underpinning are all outlined in Chapter 5, Construction Strategy and discussed in detail later in this report.

Further works in the vicinity of the bridge and to the bridge will also include:

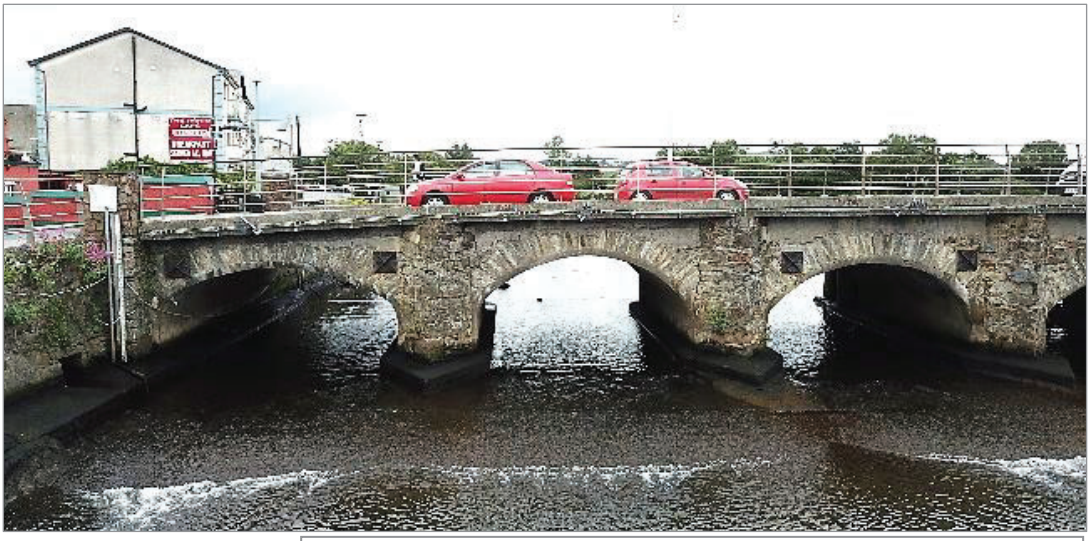
Demolition of the existing concrete scour protection slab and lowering of the floor of the bridge and the riverbed immediately upstream and downstream of the bridge. Construction of a new concrete scour protection slab (400mm thick) from 10m upstream to 15m downstream of the bridge and beneath the arches of the bridge, to a level of approximately 1m below the existing riverbed level, and the placement of riprap along the upstream and downstream edges of the scour protection slab.

Maintenance / repair works to the historic masonry will also be included as part of the overall flood alleviation works and are referred to in detail in the appendices of this report.

1.2 Description of the structure

Arklow bridge is a 19 span masonry arch structure carrying the R722 road over the Avoca river. The bridge dates from approx. 1755 and was designed by Andrew Noble. It is the longest multi span bridge in Ireland. It is indicated in the ADCO report from a 2018 instream survey that there may have been an earlier timber structure immediately upstream of the current bridge, and that perhaps the fortification in the centre is part of an earlier configuration but this has yet to be proved.
The arch spans vary from approx. 4.6m to 7m giving a total overall length in the order of 150m. The masonry bridge was approximately 6.5m wide.

The bridge was extended in the 1960's to the west, upstream side with a concrete bridge spanning between groups of three piles matching the historic pier location.
The deck surface spreads across both structures and is now approximately 11.4m wide.



Typical arch detail showing concrete downstream apron and pattress plates and also just visible spray concrete to underside of arches. Photo c/o Brady Shipman

Archaeological findings include evidence for an historic stone apron between the piers, comprising stone blocks set in mortar. While this detail exists under each arch it is mostly buried under a later concrete skim. Downstream there is a later concrete apron.

There have been significant interventions over the years.
The insertion of steel rods and pattress plates to the southern arches nos 1; 3; 5 and 6 probably dates to the same time as the addition of the concrete bridge.
There is a note of the bridge being repointed in 1982.

Larson Contracts were appointed as a specialist refurbishment contractor in 2013 and having identified defective areas of concrete, repairs were undertaken and a protective coating system applied. This reference possibly refers to the shotcrete to the underside of most of the arches.

Sketches 18572 Sk01 – Sk10 appended should be consulted for further description of the historic bridge form; current condition and proposed repairs.

1.3 Method of Appraisal and limitations of reporting and investigations

The bridge was visited 15th June 2018 by Lisa Edden of CORA Consulting Engineers. The inspection involved a visual inspection from the bridge deck and both riverbanks.

Access to the water was not gained by either boat and/or dive gear so no close inspection of underside of arches or pier abutments was made by CORA Consulting Engineers. No invasive works were carried out or samples were taken or tested by CORA.
However extensive photographic survey and reports of previous site investigations from other specialists were consulted at the outset in 2018 and then subsequently as more reports became available 2019-2021.
These reports are as listed in the appendices to this report.

Credit goes to the following consultants for photographs and reports forwarded:

- Byrne Looby drawings and technical notes (ByrneLooby)
- Brady Shipman Martin Planning and Landscape Consultant (BradyShipman);
- Courtney Deery Heritage Consultants (CourtneyDeery)
- Archaeological and Commercial Diving Company (ADCO)
- Wicklow County Council FRA and Public Consultation documents

A number of workshop type meetings have been held at which CORA attended:

- 12th June 2018 Arup offices
- 19th June 2018 Dept. Culture Heritage and Gaeltacht at Custom House Quay
- 24th August 2020 Consultant Microsoft team mtg
- 26th August 2020 Consultation with Department DCHG
- 2nd September 2020 EIAR Workshop
- 29th September 2020 Consultant Microsoft team mtg
- 30th September 2020 Consultation with Department DCHG

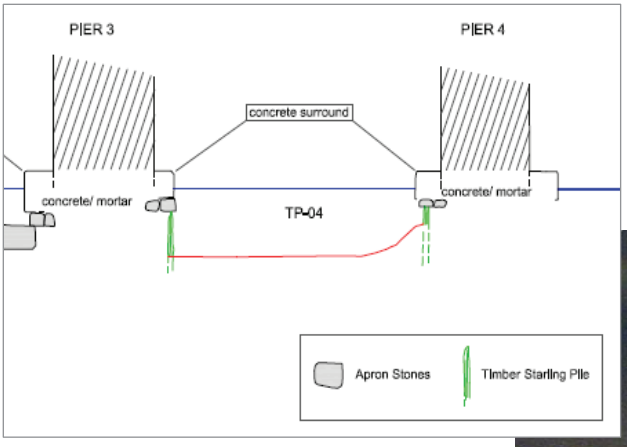
It was identified early on that there was insufficient information of the internal pier masonry and also to the bases of each pier, both the original foundations details and also the ground conditions immediately at and under the piers.

Specifically this is identified in the Byrne Looby Geotechnical Review Note PH00886/01/GEO/LT/01/00 dated 2018-07-11:

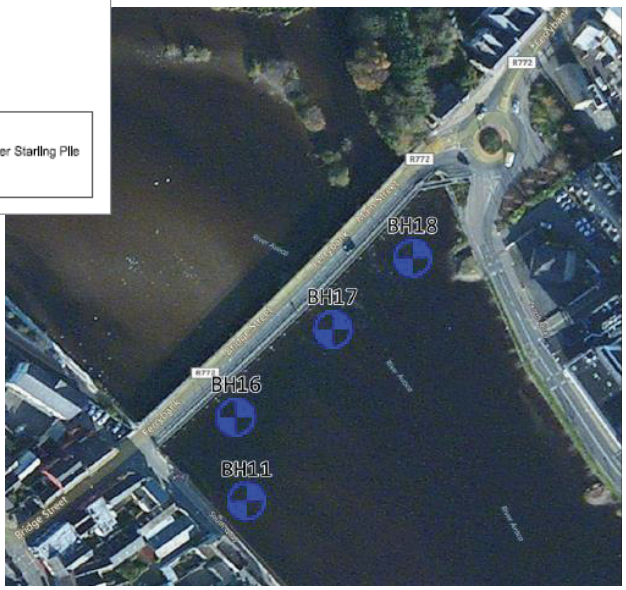
> *"No information has been provided to the ByrneLooby geotechnical team on the condition and type of foundations supporting the bridge piers. As such, further investigation works are recommended to be carried out. These investigation works should consist of coring through the piers from deck level and penetrate the base of the foundations…….. the information gathered regarding the bridge foundations would allow a detailed assessment of their condition and depth to be carried out and allow a detailed assessment and design of the underpinning requirement. Additionally, the configuration of the foundations should be determined to evaluate the extents of the underpinning requirements."*

Trial pits to the bridge piers were agreed in principle with the Dept.CHG 19th June 2018. These exploratory works were / are required to assist in developing the solutions to works in the vicinity of the piers and are essential to the understanding of the underpinning options along with consideration of any appointed contractors' methodologies.

Trial pits to the base of the piers of the southern four arches were carried out Oct– Nov 2019. This differed from the locations agreed with the department, but due to the extensive bunds required to carry out works instream this was regarded as the most practical extent of exploration at the time. The location of the exploration was also informed by the evolving proposed programme of works which has the southern third of the bridge programmed first and the middle and northern parts to follow in yearly intervals.



The details of the 2019 trial pits to arches 1-4 are recorded in detail in Ground Investigations Ireland report dated 2019-12 and the ADCO's report dated 2020-07.



The Causeway Geotech Borehole report identifies that the boreholes immediately downstream of the bridge show extensive depths of sands; gravels; silts and clays to at least 11-12m below riverbed. This is undoubtedly indicative of what lies under the piers. These strata are variable and in some are very soft.

Further review by ByrneLooby Geotechnical team summarised in the note Geotech Review B1602/GEO/LT01/01 2020-07 reaffirmed the need to explore the bridge piers by borehole from deck level and also identified the risks and mitigation measures associated with each proposed pier stabilisation method - these are included in section 2 over.
There is also mention of requirement to reassess the overall stability of the bridge to resist a 1:100 year storm and thus update the University of Sheffield report.
It is noted in chapter 4 of the EIAR that *"The detailed design of the underpinning will take account of bridge lateral stability under flood flow conditions, as well as overall structural stability, in the context of reduced flood levels upstream reducing the lateral forces, reduced bridge floor level, new pier foundations taken to suitable formation levels and all available ground investigation data.*

It is anticipated that further site investigation works will be undertaken and that site investigations will be procured during the detailed design stage of the project. This will also include a detailed assessment of the existing masonry bridge structure to fully define the extent of specialist masonry repair works required.

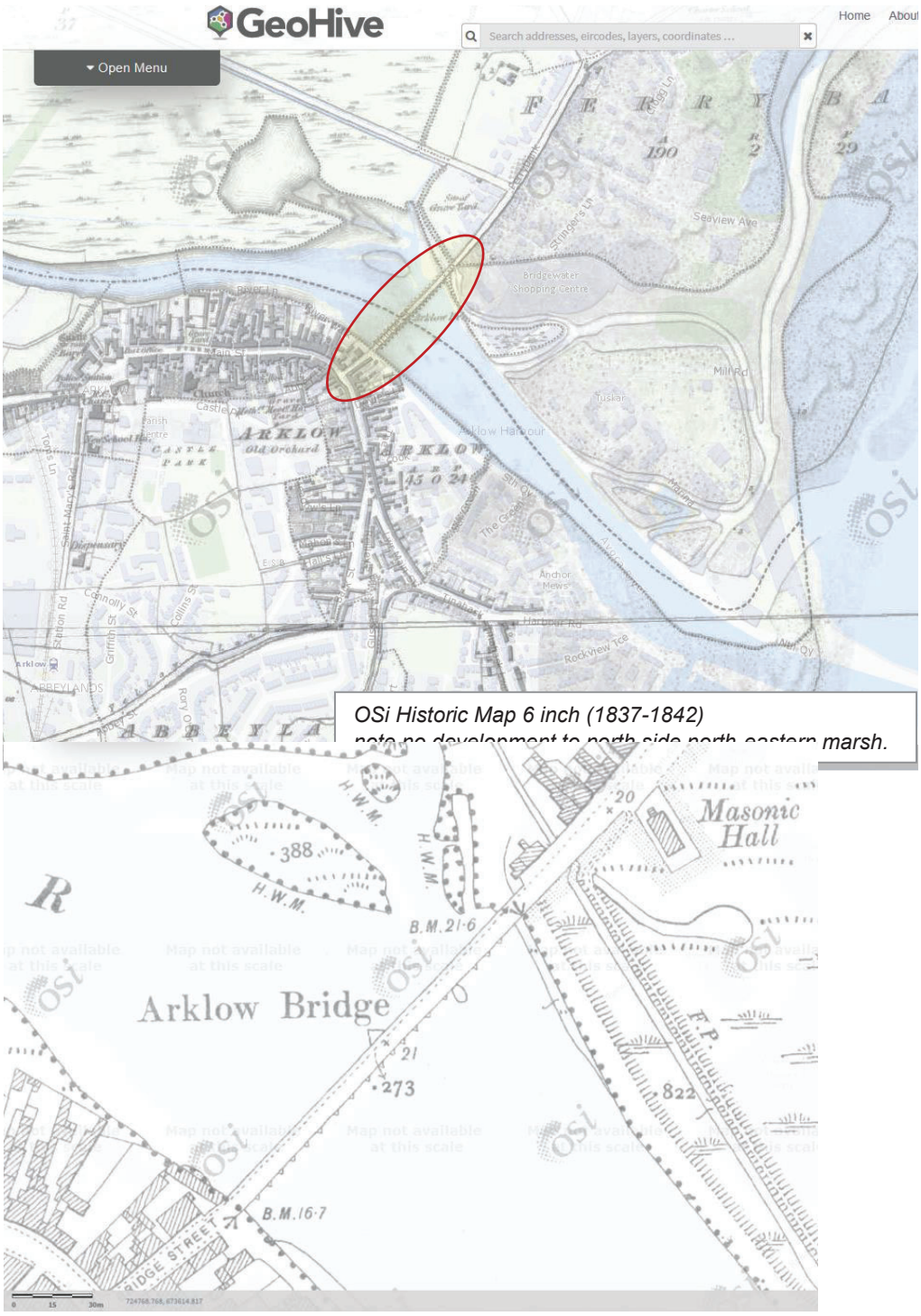
This report also includes more detailed advice and specification for the above water (low tide) masonry repairs required along with some options for retention and repair /replacement of the original anti-scour bedding in the two bankside arches where the riverbed is to remain at original bridge construction level.
Excluded are any comments on the later piled concrete bridge structure excepting where it impacts the historic masonry structure. The wider non bridge specific aspects of the flood alleviation scheme are also beyond the remit of this report.

2 Observations

2.1 The bridge in its context and the flooding issues.

The bridge forms an important arterial link. Originally linking the town to the countryside to the north of the river Avoca and now in addition linking separate parts of the town.

The historic bridge can be viewed from a distance from both riverbanks downstream and makes a significant impression on the landscape. It is obscured by the later piled concrete bridge to the northwest, upstream side.

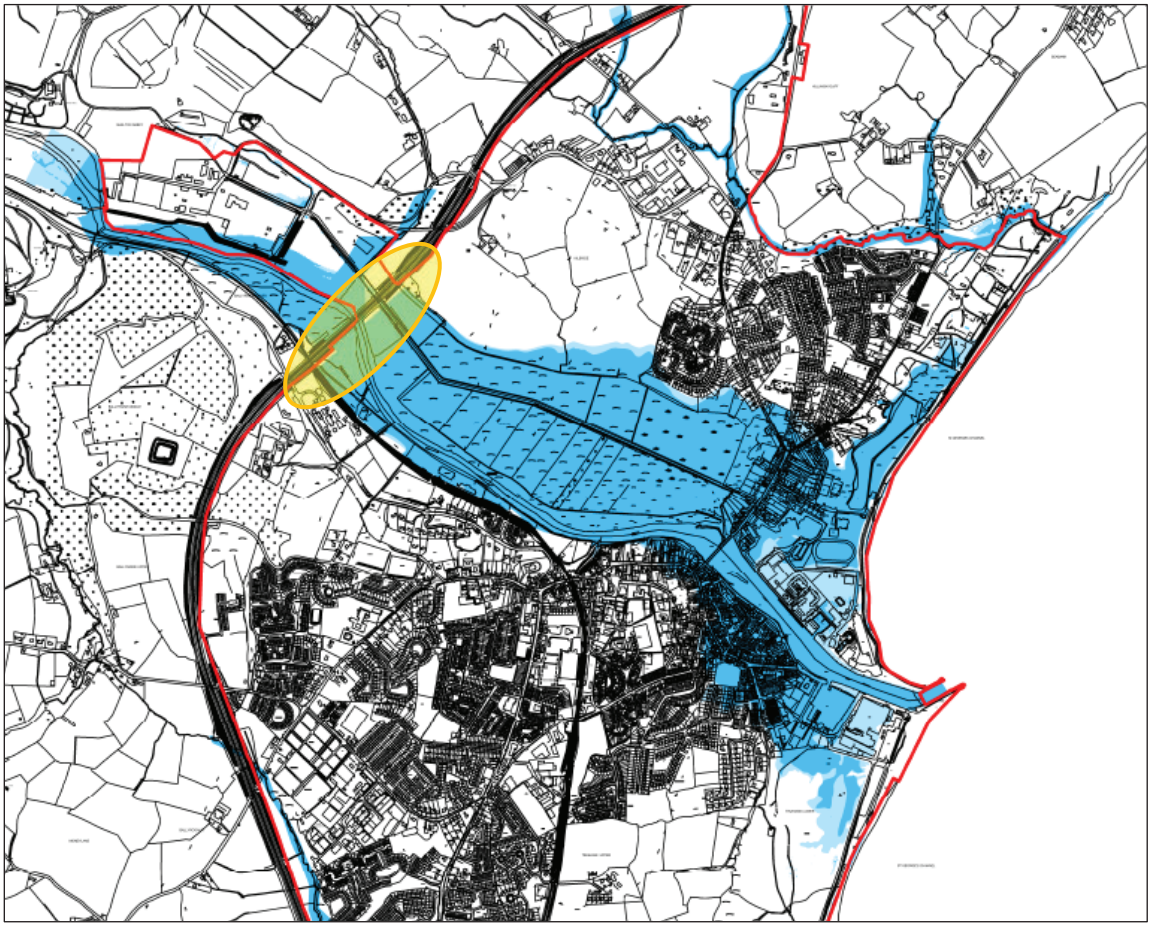


OSi Historic Map 6 inch (1837-1842)
note no development to north side north eastern marsh.

OSi Historic Map 25 inch (1888-1913)

The 1:100 and 1:200 flood risk area is indicated in the Wicklow County Council 2017 Development Plan mapping below.

The bridge has been identified as a contributary factor in this flooding risk.



WICKLOW COUNTY DEVELOPMENT PLAN 2016-2022

Arklow and Environs Local Area Plan 2017

Title: Indicative Flood Zones
Map No. : SFRA1

Wicklow County Council
Planning Department

Maps are not to scale

Settlement boundary

FLOOD ZONE A: High probability of flooding

Where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding

FLOOD ZONE B: Moderate probability of flooding

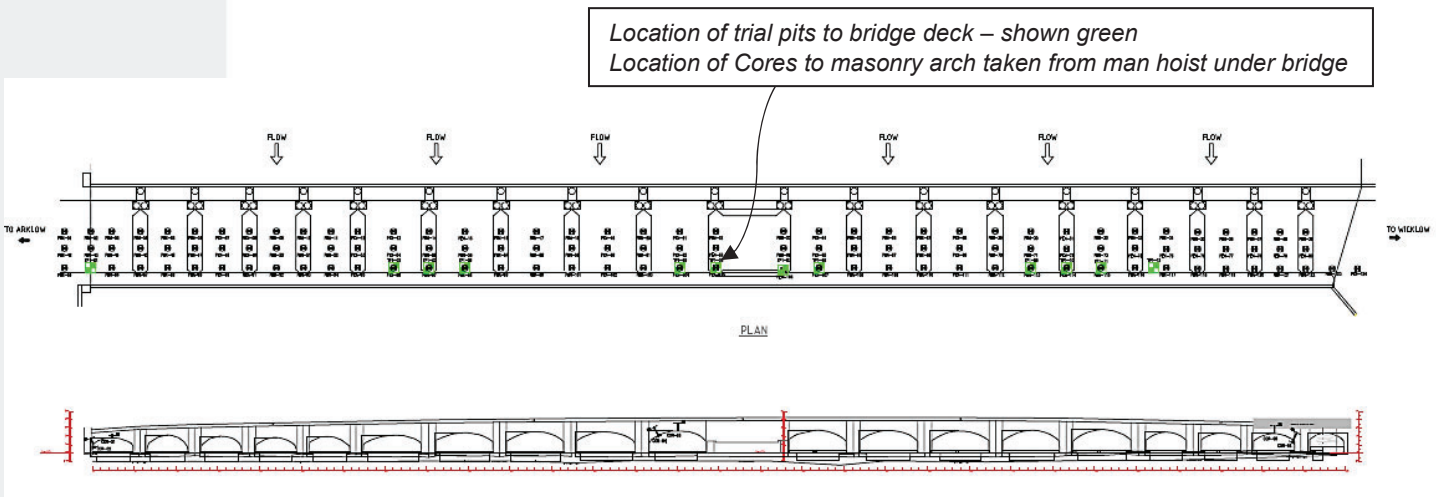
Where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding

2.2 Stability and overall condition and previous reports

Lateral Capacity of the bridge showing its response to flood waters is described in the report dated 2013 by the Dept Civil & Structural Engineering, Sheffield University.
The report assessed the capacity of the masonry arched bridge to withstand the lateral forces arising from water flow and possible debris impact forces during a 100 year fluvial flood event (200 year combined tide) in the presence of a proposed flood relief scheme.
The report states that *"Conservative calculations indicate that the bridge will be stable under these conditions but could be vulnerable to localised damage from debris impact."*
It is noted that the proposed works include for a debris trap upstream of the bridge which will significantly reduce the risk of damage from floating debris.
The report makes mentions that *"internal erosion can be guarded against by good maintenance and is not considered further in this report".* And also goes on to recommend that *"The bridge should be well maintained (e.g. mortar joints regularly pointed up) in order to guard against damage from internal erosion."*

A Scour Report "Arklow Bridge Assessment of Scour potential" date approx. 2010 was also submitted. This report focuses on undermining of the bridge piers due to scour action.
This report has relevance to the bridge in its current condition since it assesses the current riverbed arrangement and therefore does not relate to proposed future bridge geometry when riverbed lowered by approximately 1m. The report says *"It was estimated that there was a significant potential for scour at this bridge, especially for the larger central pier."*

Ground / fabric investigation of the bridge was carried out in 2010 by Whiteford Geoservices Ltd to ascertain the nature and extent of backfill material over the arches; the drainage behaviour of backfill material and the structural properties of the existing road base and backfill material.
The 12no trial pits varied in depth from 0.25m to 1.6m. The depths of the excavations typically indicating distance to top of masonry arch stonework. The masonry to the arches was not explored in the trial pits but instead from below by way of 5no 100mm diameter cores varying from 350 to 550mm long. The material of the arches is recorded as greywacke and above that forming the base to the road is free draining silty sand and gravel with minimal deck concrete and tarmac over.
No boreholes though the deck into the piers were presented.



Summary of Trial pit results (as extracted by CORA from SI report)			
Trial Pit no	Depth	Typical findings under top deck tarmac and concrete	Material encountered at base
01	0.25	Steel reinforced concrete	Concrete
02	1.1	Silty Sand and occasional cobbles	Instability of soil in excavation - trial pit stopped
03	0.57	Silty slightly gravelly sand	Masonry Arch
04	1.35	Silty gravelly sand and gravel	Masonry Arch
05	0.47	Sandy Gravel	Masonry Arch
06	0.44	Gravelly Sand	Masonry Arch
07	1.06	Sand and Gravel	Masonry Arch
08	0.96	Gravelly Sand	Masonry Arch
09	0.6	Gravelly silty Sand	Masonry Arch
10	1.5	Gravelly silty Sand	Instability of soil in excavation - trial pit stopped
11	0.47	Gravelly silty Sand	Masonry Arch
12	1.6	Gravelly silty Sand	Instability of soil in excavation - trial pit stopped

Plate 33 Masonry Core 1

Plate 34 Masonry Core 2

Report 775.01 / 08 – Arklow Bridge - Site Investigation Wicklow County Council & Arklow Town Council

Plate 35 Masonry Core 3

Plate 36 Masonry Core 4

From these reports it is indicated that the bridge is stable in its current form albeit susceptible to impact from large floating debris. The bridge abutments have a potential to be subjected to scour, the central pier in particular is susceptible.

The arch stonework is typically 430-500mm thick. From the five cores taken this appears to represent the typical length of the voussoir arch stones. It is not clear if there is further masonry construction over these arches before the gravelly silty sand backfill to the arch tops.

2.3 Maintenance and current condition

The bridge although being overall stable and functional has local areas of masonry and general upkeep that need addressing.

Sketches 18572 Sk01 – Sk10 appended show further detail and locations of the observations outlined below:

Vegetation growth is excessive to the top of the central pier and is also gaining a foothold to some areas of the vertical masonry

Mortar loss to the tidal range of the piers was observed. Continued unaddressed mortar loss leads to individual stones falling and eventually structural failure.

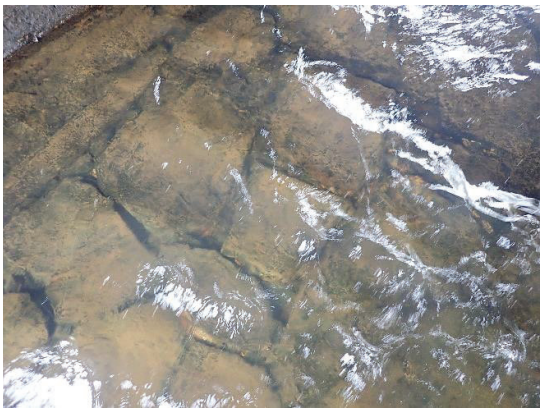
Loose stonework was observed to the weather tops of piers this is also associated with excessive vegetation. Both will lead to loss of masonry and degradation of the historic record as well as excessive water flow through masonry resulting in leaching of the mortar.

The underside of the arches have been extensively shot-creted.
This is potentially obscuring the issues it was applied to address including possible loss of mortar between the voussoir stones of the arch and thus the integrity of the arches

The previous tying works through arches 1; 3; 5 and 6 are beginning to show signs of corrosion

2.4 River bed detail and anti-scour aprons

The detail to the riverbed between piers and to some areas of the front and rear apron consists of carefully interlocking stones as anti-scour. In many places this was observed to be well executed however, under a number of arches it is largely buried under a later concrete skim. This may be original to the bridge construction however the ADCO report following the trial pits executed to the 4 southern arches late 2019 indicates that the bedding around these stones contains detritus from mid to late C20th. This could possibly be associated with repair works carried out as part of the widening of the bridge in the 1960's.
This historic detail should be retained wherever the proposed scheme allows.
Downstream is a later concrete apron, sometimes this extends between the piers.



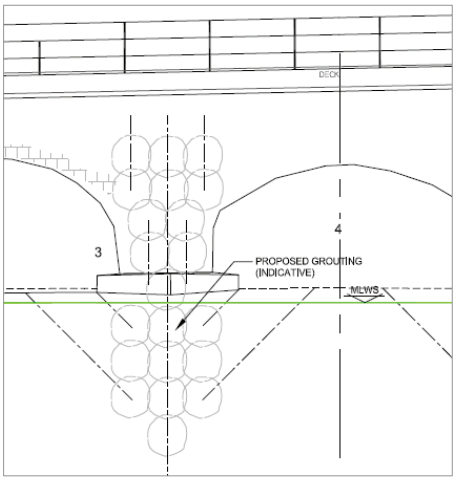
2.5 Utilities and services

It is understood that the proposed drainage upgrade will involve the location of a large mains sewer in archway No1 below the current bed level with the reinstatement of the bed back to original level.
These works present the opportunity to trial one or more of the proposed underpinning methods on pier between arches 1 and 2 and also present the opportunity to relay the riverbed with stonework retrieved from the bed and to match such.

The underside of arch No19 is completely filled with services. Whilst relocating these services is not part of the flood alleviation works consideration should be given to removing obsolete services and diverting all other utilities to allow maintenance of the bridge and improve the aesthetic of this protected structure.
The location of these services and the size of arch No19 make it unviable to excavate in this area and of little benefit for flood alleviation works. The riverbed is to be retained at current level with its original anti-scour blocking retained intact.

2.6 Proposed Reduction to Riverbed / Underpinning works

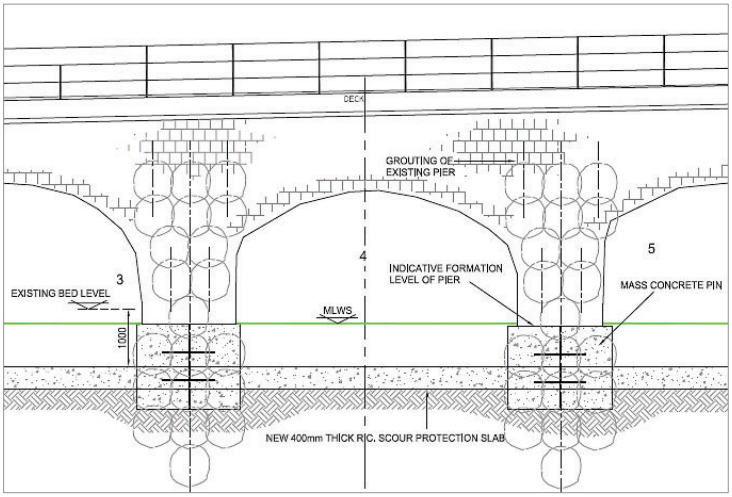
Prior to any of the proposed underpinning / piling methods grouting of all the piers is indicated on Byrne Looby drawing 88601- 1006.
It is reported that the bridge has been previously grouted yet despite extensive research the detail of this previous grouting has not been confirmed.
As part of the proposed works the requirement for exploration pre works is highlighted. At that time close up inspection of the piers will be possible and also immediately prior to any new grouting works water flushing of each and every grout injection point is proposed to firstly check if grouting is required and ensure breakout of grout will not occur.



Various methods have been proposed to stabilise / extend the depth of the piers thus allowing a general reduction of bed level 1m below existing.
These works are shown on Byrne Looby drawings 88601- 1006 through to 1010, outlined in Chapter 5 of the FRS EIA and are compared in the table in the appendix.

They are as follows:

1. <u>Traditional underpinning</u>
   Installation of 900mm wide x up to 1500mm deep concrete pins in a hit and miss sequence under the pier.



Commentary in ByrneLooby Geotechnical Review Note B1602/GEO/LT01/01 2020-07:

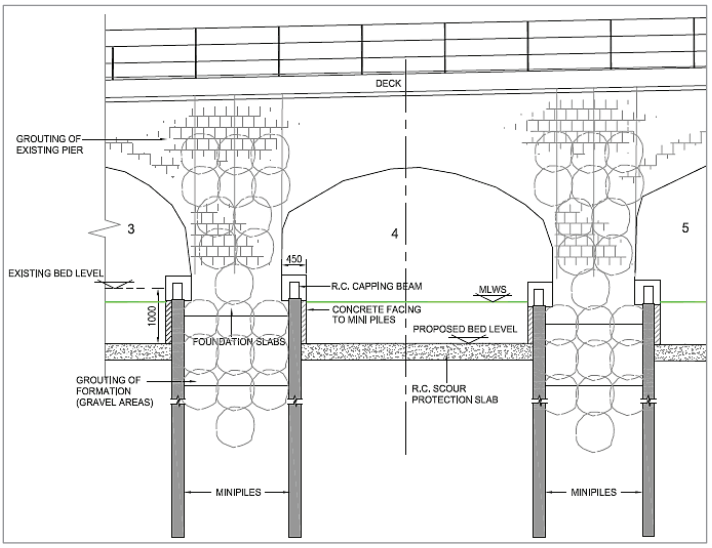
> *Underpinning of bridge structures is a well proven technique, however careful consideration of the construction sequence is needed to ensure the traditional hit and miss sequence does not negatively impact the bridge structure. Grouting under the piers, prior to the underpinning works, may be required. Substantial temporary works would be required to control water ingress into the excavations to form the underpins. These temporary works may consist of temporary bunding or sheet piles. Grouting of the underlying Sands and Gravels would be required to stabilise the material to allow the excavations for the concrete pins to be formed and to limit groundwater flow and loss of material from beneath the pier footings. The concrete pins could then be constructed in a traditional hit and miss sequence until the required area was underpinned.*

The shallow depth to the soft SILT means that traditional concrete underpinning may not be feasible across a number of the piers. Where competent material is present, the pins are likely to extend in the order of 1m below the underside of the footing. The process of completing the hit and miss underpinning sequence would be particularly onerous and may result in an extended programme but would provide a suitable solution to underpinning of the bridge, dependent on ground conditions. The control of the temporary works will be crucial in limiting movement of the bridge, and to prevent damage during the works.

2. Micro-piling from the riverbed

Approximately 70no. 200mm diameter micro-piles installed from low level around the perimeter of each pier to a suitable formation and constructing a ring beam around each pier to tie the mini piles together.

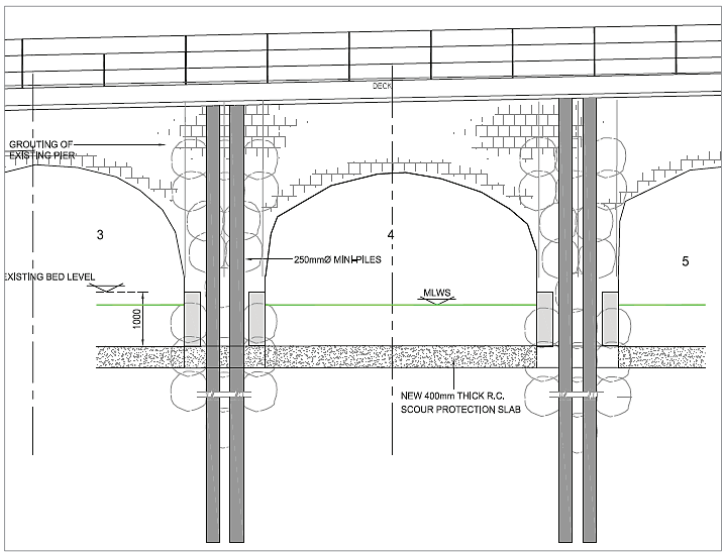
Commentary in ByrneLooby Geotechnical Review Note B1602/GEO/LT01/01 2020-07:



Approximately 2.5m to 3m of headroom would typically be required for a rig with a reduced headroom mast. Bunding around the piling area would be required to keep the area dry to allow piling works to take place. The scour slab will be removed locally along the line of the piles to receive the micro-piles. The remainder of the slab will form a working platform to carry out the piling works. Due to the limited headroom and depending on the thickness of the scour slab, it may be necessary to remove additional riverbed material from under the slab. To avoid undermining the bridge pier, any additional excavation should be carried out incrementally and the piled wall constructed in reduced lengths.
Based on likely ground conditions, piles will likely be required to be installed through the underlying soft SILT layers and founded within the underlying medium dense GRAVEL/ very stiff CLAY. The pile type and pile length is subject to detail design.
It is unlikely that a traditional secant pile arrangement can be facilitated in this working space and therefore a contiguous arrangement is expected. This will include nominal gaps between adjacent piles, through which loss of granular material may occur. As a result, prior to any works, grouting beneath the piers and around the existing piles on the upstream side may be required to prevent loss of ground between the contiguous piles.

3. Mini-piling from bridge deck level

12no. 250mm diameter bored cast insitu RC piles installed from bridge deck level through each pier. The face of the piers would then be extended down by cladding these piles with an underpinning skin to the perimeter of the piers.

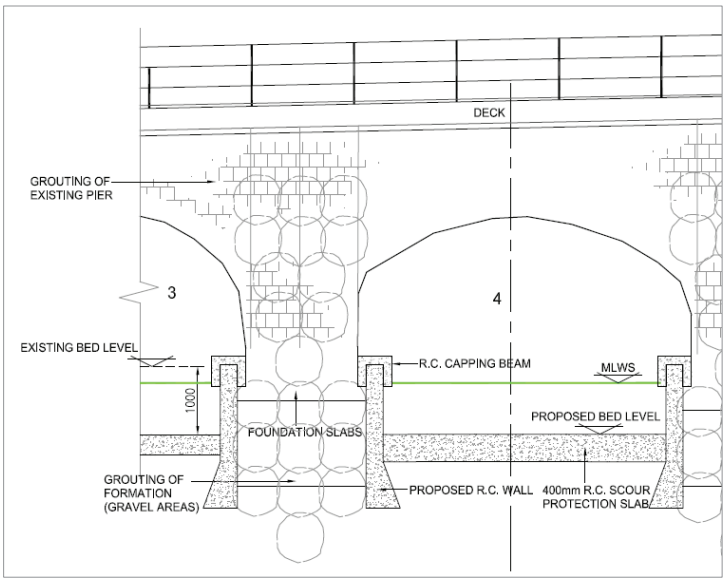


Commentary in ByrneLooby Geotechnical Review Note B1602/GEO/LT01/01 2020-07:

Installing piles in this way would include nominal gaps between adjacent piles, through which loss of granular material may occur. As a result, retaining this material will need to be considered during the design. This may be carried out by grouting beneath the piers and around the existing piles on the upstream side, or by encasing the footings in concrete walls to support the existing material.

4. Extensive formation improvement

Where the soils at formation level are suitable, extensive grouting will be deployed to take the load from the piers to a suitable level. The riverbed will then be reduced to formation level for the concrete scour protection and a reinforced concrete wall installed around the perimeter of each pier from the existing masonry level to 900mm below the proposed bed level.



This proposal has been developed since the last Byrne Looby Geotechnical review and would appear to benefit from a holistic approach based on assessment of all the other methodologies.

3 Opinion and recommendations

3.1 The bridge in its context.

The bridge as viewed from downstream from either bank is part of the Arklow landscape and represents an important feature on the horizon and a main arterial link. The proposed works should not detract from this important heritage feature and also present an opportunity for the repair and enhancement of such, which should not be overlooked.

3.2 Bridge Stability and impact of proposed works.

The current overall stability of the bridge has been investigated by others and has previously been deemed satisfactory however any proposed works such as: traditional underpinning; micro-piling from riverbed; mini-piling through the bridge and/or extensive formation improvement along with lowering the river bed are not without risk.
With the appropriate design as described in Chapter 4 of the EIAR and the Construction Methodology as described in Chapter 5 of the EIAR, the risk can be properly and effectively managed.

The additional findings of various site investigations particularly borehole investigations immediately downstream of the bridge have thrown into question some of the assumptions of earlier reports. This is noted in Geotech Review Note B1602/GEO/LT01/01 2020-07:

> *"……. as additional information is now available regarding the bridge's foundations and underlying ground conditions, it is recommended that the University of Sheffield reassess their assessment to validate their assumptions. Additionally, it is not clear as to whether the assessment takes account of the lowering of the floor of the bridge arches and it is recommended this is clarified."*

The requirement for the assessment of the lateral stability of the bridge has been noted in Chapter 4 of the EIAR thus "*The detailed design of the underpinning will take account of bridge lateral stability under flood flow conditions, as well as overall structural stability, in the context of reduced flood levels upstream reducing the lateral forces, reduced bridge floor level, new pier foundations taken to suitable formation levels and all available ground investigation data. The improved flood conditions, robust design and proposed construction methodology as set out in Chapter 5 – Construction Strategy will ensure that the structural integrity of Arklow Bridge is enhanced.*

Other risks are summarised in the table in appendix.

Further site investigation works are required to fully understand the existent conditions:

- the pier masonry condition and thus the regime for any additional grouting.
- the existing foundation detail including the presence and condition of starling piles.
- the ground conditions under the piers.

Further site investigation is essential before a final scheme for the additional support to the underside of the current piers can be arrived at. A generous period has been identified in the programme for additional specialist investigation by the appointed contractor along with detailed design to establish which of the four alternative underpinning methods is appropriate at each and every pier.

Not only will the final proposed underpinning details be important to de-risking the works but also the appointed contractor's proposed method and sequence of working will be highly critical in maintaining the overall stability of the bridge. The appropriate stipulations must be incorporated into all tender and construction documents to make sure the process of thorough review and assessment of methodologies can be carried out.

3.3 Maintenance and repair works of the historic fabric

The bridge although being stable and functional has local areas of masonry and general upkeep that need addressing. If this important maintenance and repair work is left undone the overall stability will be jeopardised long term.

These maintenance / repair issues include the following non exhaustive list:

- vegetation growth
- mortar loss
- loose stonework
- corroding ties
- obscured issues behind later shotcrete.

Sketches 18572 Sk01 – Sk10 appended outline the observations of the existing fabric and repair works required.

3.4 River bed adjustments and anti-scour

An earlier anti-scour riverbed detail is still existent in many places which takes the form of large interlocking stones. This will be lost when the riverbed is lowered in arches 2 through to 18. Where possible this detail should be retained and/or reinstated.
There are two locations where this may sensibly occur:

- Arch no1 adjoining the south bank where the riverbed is to be reinstated at current level over the new main sewer.
- Arch 19 adjoining the north bank where the existing riverbed level is being maintained and repairs to the existing anti-scour interlocking stonework may be necessary.

3.5 Services and utilities

Existing services run through Arch 19 and whilst their re-location is not part of this flood alleviation scheme, their removal longer term should be considered thus allowing proper repair and maintenance and visual enhancement of the historic structure.
The proposed service installation to Arch no1 below riverbed level will allow further exploration of the below riverbed detail and also presents the opportunity for reinstatement of historic riverbed features – see above
This essential upgrade work to main sewer should be promoted for its opportunities in discovery for the flood alleviation contract.

3.6 Proposed grouting; underpinning; mini piling and piling

Grouting is irreversible and the fabric of historic masonry structures is changed by the introduction of grout to its core. The presence of a harder impervious grout can potentially change the way masonry units weather and has the potential to promote deterioration of the stonework.
It is suspected that the bridge has been previously grouted, albeit the extent of this is unknown. Significant adverse effects have not been noted to date.

It is anticipated that further site investigation works will be undertaken and the contract for the site investigations will be procured during the detailed design stage of the project. This will include a detailed assessment of the existing masonry bridge structure to fully define the extent of specialist masonry repair works required. This will also likely confirm the existence of any previous grouting and allow a more sympathetic grouting regime to be established should grouting be needed to the piers themselves.
Grouting to the substrate below the pier foundations is not deemed as being an issue to the historic structure.

3.7 Underpinning; micro-piling; mini-piling; formation enhancement.

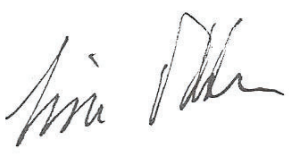
The appointed construction contractors will also carry out their own site investigations to better inform their own working methods including temporary works designs.

The four methods proposed to stabilise / extend the depth of the piers to allow a general reduction of bed level 1m below existing have the potential for very different consequences on the existing bridge:

- Underpinning if carried out carefully will leave the bridge in its original form. The trial pits excavated late 2019 indicated Starling piles under the foundations, no doubt installed to strengthen the ground and help prevent scouring under the piers This detail will be removed by underpinning, however Archaeological investigation during underpinning will ensure that preservation by record takes place at each location where a starling post is encountered. The soil type found under the piers will be critical to the success of any underpinning. Some of the downstream boreholes indicate softer ground at lower levels and therefore the depth of the underpinning may become critical in certain instances and indicate that a different solution such as piling is required.
- Micro-pilling around the base of the piers is probably the least intrusive or risky to the original structure but visually leaves a larger “boot” to each pier and will obscure the original masonry at the bottom of each pier. This will however be non-visible much of the time as it is typically below the low tide line.
- Mini-Piling through the piers has the biggest disruption to the actual fabric as the process cores down through the original structure. This methodology will also definitely require grouting. However this method is probably visually the least intrusive thus allowing better interpretation of the historic structure long term.
- Extensive formation improvement involves, where the soils are suitable, grouting below the piers to take the loads to a lower stratum. A reinforced concrete wall is then cast around the base of each pier. This proposal benefits from a holistic approach but as with the Micro piling option will leave a boot to each pier base.

Further site investigation is essential before finalising the solution to the extension of these piers. It has also been mooted that there may indeed be a different solution for different piers. The phased programming of a third of the bridge per year is welcomed and it is strongly advised that site investigation for the following phase is a perquisite of the previous phase if not carried out prior to first commencement.

Prepared by;



Lisa Edden BEng CEng MIStructE MIEI

for CORA Consulting Engineers

4 Appendices

4.1 Reports / information received and referred to in report
4.2 Comparison of advantages/disadvantages of underpinning options
4.3 Specifications for vegetation removal + masonry repair works
4.4 Drawings showing current condition and advised repairs

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Conservation Engineering Report
Arklow Bridge, Arklow, Co Wicklow

Conservation Engineering Report on existing Masonry 19 Arch bridge and advice regarding impacts of proposed Flood Alleviation Scheme on the bridge.

4. Appendices

1.1 Reports / information received and referred to in report
1.2 Comparison of advantages/disadvantages of underpinning options
1.3 Specifications for vegetation removal + masonry repair works
1.4 Drawings showing current condition and advised repairs

4.1 List of information received and referred to in report

Technical information received and referred to in compilation of issue 1 and further information received post 2019-09 which has further informed issue 2.

Previous Civil & Structural Analysis and site investigations of Arklow Bridge

▪ Load Carrying Capacity rev-A	University of Sheffield	2011
▪ Assessment of Scour potential	University of Bradford	2010
▪ Site Investigation	Whitford Geoservices Ltd	2010
▪ Geotech Review PH00886/01/GEO/LT/01/00	Byrne Looby	2018-07

Geotechnical & Archaeological Reports received 2019-12 onwards, after 1st issue

▪ Ground Investigations Ireland Arklow Bridge	2019-12
▪ ADCO_17E0482_Arklow Bridge	2020-02
▪ ADCO_17E0482_Arklow Bridge final issue	2020-07
▪ Causeway Geotech Borehole information	2018-01

Geotechnical Reports received 2021-03-08, after 2nd issue of report

▪ Geotech Review B1602/GEO/LT01/01	Byrne Looby	2020-07

Drawings from Byrne Looby Consulting Engineers received 2018 – March 2021

- 88601-1001-P2 Site Location Plan
- 88601-1002-P3 Overall Scheme Layout
- 88601-1003-P4 Overall Layout
- 88601-1004-P1 Existing Layout
- 88601-1005-P1 Proposed Layout
- 88601-1006-P0 Grouting Works
- 88601-1007-P0 Option 1 Underpinning
- 88601-1008-P0 Option 2 Contiguous mini piles
- 88601-1009-P0 Option 3 Piles through piers
- 88601-1010-P0 Option 4 RC surround wall
- 88601-1046-P3 South Bank & Arch 1

Construction Strategy compiled by Byrne Looby with dates received.

- Arklow FRS EIA - Chapter 5 (Construction Strategy)_Draft1 2020-10-02
- Arklow FRS EIA - Chapter 5 (Construction Strategy)_Draft3 2020-10-15
- Arklow FRS EIA - Chapter 5 (Construction Strategy)_Draft4 2021-03-08

Additional draft sections of EIA received received 2021-03-08

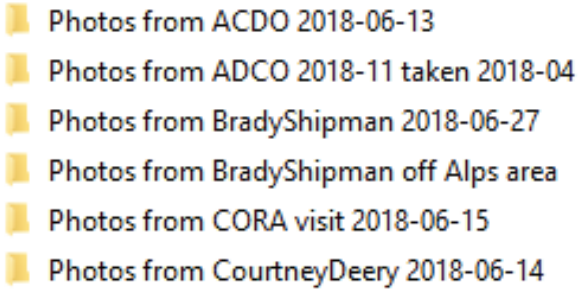
- Arklow FRS EIA - Chapter 4 (Proposed Scheme) Draft 3
- Arklow FRS EIA - Chapter 11 (Archaeology; Architectural & Cultural Heritage) Draft 1

General background information received and referred to

General reports on Heritage and Arklow Flood relief Scheme

▪ Cultural heritage	Courtney Deery	2018
▪ Flood Relief Scheme (Summary of Public Consultation)	Wicklow / OPW / Arup	2017
▪ Arklow and Environs Local Area Plan (Appendix C Strategic Flood Risk Assessment 2018-24	Wicklow Co.Co.	2017

Photographs as follows:



4.2 Comparison of advantages/disadvantages of proposed works including underpinning options

Table originally compiled by Courtney Deery Archaeologists June 2018,
Additional comments by CORA Consulting Engineers for issue 1 of Conservation Engineering report
Further comments issue 2 of report after consulting Construction Strategy 2020-10
Additional comments regarding mitigation of Risks 2021-03 for issue 3

Intervention	Location/ Extent	Reason	Advantages	Mitigation of risks
Grouting	Within the existing structure of the original masonry bridge and in the natural granular material beneath the piers and beneath the riverbed.	To improve the structural integrity of the original masonry bridge and the natural material beneath the bridge piers, to assist in the control of ground water, to prevent the washout of fines during dewatering operations. To improve the safety of operations in excavations during archaeological testing and construction.	Reduces risk of damage to old masonry stone bridge due to temporary works e.g. excavations and dewatering, reduces risk of damage old masonry stone bridge due to settlement. Proven Technique at Brandon Bridge No visual effect *Note grouting beneath foundation to masonry piers regarded as non-detrimental and essential where ground investigation shows soft or loose subsoil conditions.*	Potential risk of loss of grout causing environmental damage; potential risk of movement of loose masonry if grouting is over-pressurised. *Exploration of each and every grouting point is required using water flushing to establish grouting methodology and allow control of the effect of grouting.* Significant traffic disruption across bridge *for the grouting of upper parts* *Grouting may cause impervious barrier at certain levels and encourage the production of lime leaching above and or deterioration of stonework.* *Detailed investigation of masonry to be carried out prior to any grouting works and grouting to be limited within existing masonry.*

Intervention	Location/ Extent	Reason	Advantages	Mitigation of risks
Underpinning options 1- 4 Note a combination of options may be deployed depending on specific ground conditions at each pier. The final choice will be developed by the chosen contractor and after the more detailed site investigation period.				
1) **Traditional Underpinning**	Under the existing piers, *involving removal of material from underside of original* foundation level *down to approx. 300mm below underside of proposed scour apron (approx. 1.5m below current riverbed level)*	To extend the structural supports of the bridge to a suitable formation below the proposed new riverbed level	Retains / improves structural capacity and integrity of the bridge. *No additional width of piers / pier bases thus greater aperture for flood waters.*	Risk of structural damage / settlement if *strict methodology not adhered to.* Requires significant temporary works within the river – seasonal restrictions, flood risk, environmental risk. *Starling piles found during 2019 site investigations will need to be cutdown / removed to allow location of underpins.* Height to span ratio of each arch will increase thus altering appearance of the bridge. *This occurs below all but the lowest spring tide water levels so will have little effect.* Exposed concrete finish to pins though mostly not visible below water level.
2) **Micro-piling *from riverbed* followed by concrete facing and capping beam to mini piles**	*Rotary drilling of approx. 70no, 200mm diameter piles* Continuous around each pier except at arch 1 and 19. *Followed by concrete facing and concrete ring beam*	To retain the existing material under the piers *allowing* the lowering of the bridge floor. to retain the bearing capacity beneath the piers.	Removes risks associated with excavating beneath the piers. reduces the safety risks by eliminating excavations *under the piers.* Avoids need for *extensive* dewatering with associated settlement risks. *Depending on how close to the pier shaft piling carried out the Starling piles may be retained.*	Requires significant temporary works within the river – seasonal restrictions, flood risk, environmental risk. *Restrictions on machinery operating under bridge arches because of reduced head room.* Height to span ratio of each arch will increase thus altering appearance of the bridge *This occurs below all but the lowest spring tide water levels so will have little effect.* Additional approx. 800mm to the width to each pier. Exposed concrete finish to mini piles though mostly not visible below water level.

Intervention	Location/ Extent	Reason	Advantages	Mitigation of risks
***3) Mini Piling from Bridge Deck* followed by concrete facing**	*Approx. 12no. 250mm diameter piles bored* through each of the masonry bridge piers. *Followed by facing concrete immediately under existing pier edge.*	To support the bridge piers *and extend the bearing down to a lower stratum.* *The concrete facing will allow the reduction of the riverbed*	Reduces risks associated with excavating for full concrete pins beneath the piers. Reduces the safety risks by reducing *extent of* excavation *under the piers.* Avoids need for extensive dewatering with associated settlement risks.	Significant traffic disruption across bridge during works. *Careful programming required to reduce traffic congestion.* *Boring operations will encounter time restrictions as busy road bridge and residential area. If deployed vibration monitoring and noise monitoring required along side restricted working hours.* Potential risk of damage during boring operation for piles e.g. if boulders are encountered. *Vibration monitoring required with sensitive limits and live monitoring feedback to operatives.* Height to span ratio of each arch will increase thus altering appearance of the bridge. *This occurs below all but the lowest spring tide water levels so will have little effect.* Exposed concrete finish to concrete facing though mostly not visible below water level. *Starling piles unlikely to be retained– Archaeological record to be made.*
4) Extensive Formation Improvement	*Where soils are suitable extensive grouting under the piers is proposed followed by an RC wall to the perimeter of each new pier base.*	*To retain and enhance the existing material under the piers.* *The RC walls allowing the reduction of the riverbed*	*Removes risks associated with excavating beneath the piers.* *Reduces the safety risks by reducing extent of excavation under the piers.* *Starling piles may be retained.*	*Requires temporary works within the river – seasonal restrictions, flood risk, environmental risk.* *Height to span ratio of each arch will increase thus altering appearance of the bridge though mostly below water level.* *Additional approx. 800mm to the width to each pier.* *Exposed concrete finish to mini piles though mostly not visible below water level.* *Starling piles unlikely to be retained – Archaeological record to be made.*

Intervention	Location/ Extent	Reason	Advantages	Mitigation of risks
Lowering the riverbed floor under the bridge.	*From approx. 15m u/s of Arklow Bridge to approx. 20m d/s* *Dimensions include for the apron toes and laying of riprap.*	*To improve river flows during flood events*	*Reduces height of flood defence walls and embankments u/s of Arklow Bridge by approximately 500mm. Little visual impact as mostly below water level.*	*Working in estuary with risk of environmental impact and seasonal working restrictions. – refer to reports by others.* *Removal of earlier stonework anti scour aprons required. Mitigate by reinstating stonework in arch 1 and repairing that in arch 19*
Scour apron	*From 10m upstream of newer bridge to a minimum 15m d/s of the original masonry bridge*	To provide scour protection to bridge piers at new riverbed level.	Provides structural resilience to bridge. Little visual impact as mostly below water level.	Working in estuary with risk of environmental impact and seasonal working restrictions. – *refer to reports by others.* *Where riverbed to be reinstated (arch 1) / left at current levels (arch 19) the use of the anti-scour stone masonry will add to the interpretation of river bed form*
Removal of vegetation	*Ref Appendix 4.4 of this report*	To protect structural integrity of masonry stonework	Improves resilience of bridge Improved appearance	*Limitations to effectiveness of vegetation removal because of restrictions on biocide near water course. This can be mitigated by allowing for ongoing maintenance to ensue control of vegetation*
Repointing	*Ref Appendix 4.4 of this report*	To protect structural integrity of masonry stonework	Improves resilience of bridge	*Extensive scaffolding / access arrangements required for works. Competent Contractor will have no issues.* New mortar appearance until weathered.
Localised repair	*Ref Appendix 4.4 of this report*	To protect structural integrity of masonry stonework	Improves resilience of bridge	*Extensive scaffolding / access arrangements required for works. Competent Contractor will have no issues.*
Sewer pipe	Placed through an existing arch, adj to south bank	To avoid risk of damage to existing services and buildings along South Quay.	Reduced construction risk to services and buildings *Opportunity to re-use stone anti-scour thus display original detail*	*Installation forms part of separate contract and documentation for that project should be consulted.* Impacts on river flows – *one arch out of another 17 not lowered. Benefits in this is beside south bank and riverbed can be retained at original levels*

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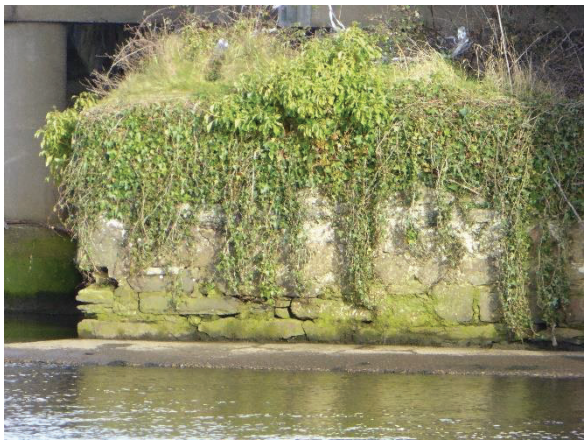
4.3 Specifications for vegetation removal + masonry repair works

Specification for Containment of Vegetation pre-works

When / where NO masonry works are envisaged to remove excessive plant growth in interim period

To areas where no immediate construction works proposed but the removal of vegetation required for access / inspection / to reduce windage on masonry etc.



General – before starting

Vegetation treatment / cutting / removal should ideally occur within the period 1st September to 28th February (dates inclusive) to comply with the Wildlife Act 1976 (Amendment) 2000. www.npws.ie/legislation

Although the removal of structure endangering plant growth outside of this period is not illegal, consultation with the National Parks and Wildlife Service is advised where substantial removal of vegetation is envisaged.

It is possible that bats are roosting in dense plant growth and cutting of the plant foliage should only occur after inspection by a qualified bat ecologist, who will recommend appropriate mitigation measures. All bat species are protected under the Wildlife Act and it is prohibited to interfere with their roosts.

Only very specific use of herbicides or biocides as mentioned below is to be deployed at any stage as the general policy is to reduce the plant growth but not kill the plants until such time as masonry works ae due to commence.

Access for works

Extreme care must be taken when removing plant growth from masonry at high levels and over water to reduce the risk of injury from falls, drwoning and from falling masonry. Full risk assessemtns must be carried out and the approitate safety measures and access put in place.

Disposal of waste

All vegetation waste should be removed to area where safe to collect ready for collect for disposal. The waste must be disposed of correctly and in accordance with the Waste Management Acts 1996 to 2011.

https://www.citizensinformation.ie/en/environment/waste_management_and_recycling/waste_management.html under which parties disposing of the waste must be licensed.

Cutting of plant growth on/in masonry walls / piers

For maintenance / control of growth and / or survey and assessment purposes where no immediate repair works are planned.

All the plant growth growing from the sides or top of the masonry should be clipped back to reduce the canopy without interfering with the part of the plant that is actually in the masonry. This will reduce the demand on the root system and also reduce the risk of wind damage to the structure. Reduction of the vegetation also allows for better inspection of the masonry for surveying and assessment of the structures.

The vegetation may be mechanically trimmed initially but then carefully cut close to the masonry face by hand. Hedge trimmers; croppers and bow saws are likely to be the appropriate tools for this job.

It is extremely important not to pull any plants or roots away from the masonry as this will dislodge stones and mortar.

Large overhanging weighty sections should be sequentially cut back in segments smaller than the remaining section such that the weight of partially cut material doesn't drag and pull the whole plant and possibly masonry behind it.

Note Removal of roots and vines attached to the walls and growing from the walls should only happen alongside masonry repair works to the bridge at a later date. There is to be no general herbicide treatment at this stage excepting that as below to woody stems.

Woody stems growing out of tops and sides of walls

Where woody stemmed plants / trees are found growing out of walls or within 1m of base of walls cut back root close to face of wall / ground and paint suitable root killer on cut stem within one hour of cutting.

All roots / stems over 30mm diameter to be treated with EcoPlug by Monsanto or similar approved, treatment to be carried out in accordance with manufacturers instructions.

Typically:- Treat within 2 days for optimum performance.

Using the prescribed drill bit make the appropriate number of holes in the living part of the stump just inside the bark. Each hole should be 25-30mm deep, 13mm wide.

Place an EcoPlug Max in each hole with the narrow end first. The top of the plug will protrude by about 10mm.

Tap each EcoPlug Max until the head is flush with the stump. This will force out the sides of the plug and release the glyphosate

Useful References:-

“Ruins – The conservation and repair of masonry ruins” ISBN 978 1 4064 2445 4

Department of Culture, Heritage and the Gaeltacht Architectural Heritage Publications & Conservation Advice Series:

https://www.buildingsofireland.com/FindOutMore/#d.en.2755

“ Bats, Birds, Buildings and You! The Heritage Council

“Bats in Buildings” Guidance notes for planners, engineers, architects and developers https://www.batconservationireland.org/wp-content/uploads/2013/09/BCIrelandGuidelines_Building.pdf

http://invasivespeciesireland.com/

“The Herbicide Handbook: Guidance on the use of herbicides on nature conservation sites”

Published by English Nature 2003 in association with FACT. ISBN 1 85716 746 5

Specification for Containment of Vegetation at commencement of works

CONSTRUCTION PHASE

Treatment of vegetation growing on and in the walls

prior and during repair works to masonry.

See also previous section for vegetation removal where no works envisaged

Leave all growth in place and carefully weed wipe or inject but do not spray those plants growing from the walls with Glyphosate such as Round-up Pro Bioactive or similar approved. Apply according to manufacturer's instructions.

https://www.monsanto-ag.co.uk/ireland/

https://www.monsanto-ag.co.uk/roundup/roundup-amenity/

The herbicide should be applied as long as possible, at least 2 weeks, before any removal of growth. This will serve to kill embedded root systems deep in the fabric of the masonry.

Removal of vegetation

After a minimum of two weeks all the plant growth growing from the sides and tops of walls should be clipped back hard. The vegetation may be mechanically trimmed initially but then carefully cut close to the building by hand.

Hedge trimmers and croppers are likely to be the appropriate tools for this job.

It is extremely important not to pull any plants away from the masonry walls as this will dislodge stones and mortar.

Any large or deep-seated roots are to be left in place during trimming operation so that they can be further treated – see procedure above for Woody stems.

Apply according to manufacturer's instructions Roundup Pro Bioactive or Eco-plugs or similar approved, to the cut faces of large stumps within 48 hours of cutting. A soluble die will help in identifying which stumps have been treated.

Proceed with masonry repairs

Dig out as much of root as is practicable as masonry works proceed, without dismantling large sections of currently stable masonry. If in doubt consult Engineer. Where roots remain drill and inject as for **"Woody stems growing out of tops and sides of walls"** in specification notes above

Specification for Masonry repair works

Note final mix designs and methodologies to be a result of consultation with Lime suppliers; Cora Engineers; Conservation Architect/Archaeologist and appointed Contractor and will be based on exemplars and a more thorough understanding of the previous construction obtained during masonry works preparation and any localised dismantling of breakwater tops.

Exemplars will be required for each pointing / rebuilding type and are to be agreed with the design team before undertaking any work.

Mortar Binder

The use of Portland Cement shall not be permitted for this work. All mortars for repairs to the historic masonry including rebuilding of new sections of traditionally constructed walls will be lime and sand mixes as specified in this section.

Lime for structural repairs should be Naturally Hydraulic Lime NHL or indigenous quicklime.

There will be instances where a quick set is desirable because of the inherent wet conditions particularly areas below the high water mark and the need to work in times outside of the ideal temperatures for lime because of the programme. Prompt Natural Cement should be sourced for these situations.

Metastar 501 pozzolan will be permitted for situations such as exposed wall tops.

Hot Mixed Lime mortars using indigenous quicklime as manufactured by Clogrennane, Co. Carlow should be considered for rebuilding. For masonry wall re-building it is proving a much quicker, more robust way of rebuilding rubble stone masonry and the expansion during slaking will be inherently useful in tightening up the arch voussoirs. The document “Hot Lime Mortars - HLM Project - TECHNOLOGY TRANSFER & APPLIED RESEARCH” should be consulted (see references).

Naturally Hydraulic Lime; Metastar; Prompt and quick lime for hot mixing are all supplied by the following (not exclusive list)

- Stoneware Studios, Youghal www.stonewarestudios.com
- Traditional Lime Co, Carlow. www.traditionallime.com

All lime mortars should be prepared and mixed as recommended in manufacturer's printed guidelines. Bags of lime hydrate, natural cement, etc. must be stored off the ground in a clean, dry place and not used outside of the dates recommended on the bags. Quicklime should be stored in weatherproof airtight bags/containers.

Sand

Shall be clean, coarse, well-graded sharp sand.

Particle sizes should range from 3mm to fine dust for any ashlar repointing and 5mm to fine dust for repointing larger joints in stonework. The sand colour is important in achieving a good visual match to the existing mortar.

Mixing

Lime and sand should be carefully measured by volume, using batching boxes (shovels are not sufficiently accurate to be used). A conventional cement mixer may be used. Add lime and sand dry and mix thoroughly. Lime hydrate and sand must be mixed dry in a mixer for a minimum of 20 minutes prior to the addition of water, to encourage air entrainment and improved workability.

Add water carefully until mixture starts to run. It should be a little dryer than a cement-sand mix. After water is added allow a full twenty minutes further mixing. The long mixing period helps improve workability.

The mortar should be damp but not too wet. Mortar for re-pointing needs to be dryer than that used for original bedding because it is being placed in small quantities in a vertical situation. Use mixed mortar within a few hours and do not moisten to extend the working life. Mortar when mixed must be used within the time scale recommended by the manufacturer.

Mix proportions

Mortar for laying and pointing Masonry (all quantities batched by volume):-

- 1 part Naturally Hydraulic Lime NHL3.5 (upper band width NHL3.5 spec)
- 1 part Prompt Natural Cement
- 2 parts 5mm down washed sharp sand + addition of up to 10% 10mm aggregate

Note. The Prompt Natural Cement in these ratios will give an initial set in approximately one hour of placing without dramatically increasing brittleness or reducing longevity. Details of Prompt refer to www.vicat.fr/en/Activities/Cement/Prompt-natural-cement.

The very lowest sections of masonry that are barely exposed at low tide may need to be repointed with mortar batched entirely of Prompt binder to avail of reduced setting times.

Limecrete for core bedding (all quantities batched by volume):-

- 1 parts Naturally Hydraulic Lime NHL3.5 (upper band width of NHL3.5 spec)
- 1 part Prompt Natural Cement
- 2 parts 5mm down washed sharp sand
- 2 parts rounded estuary, river or sea pebble up to 10-18mm in size
  (The last two constituents can be replaced with 4 parts well graded 20mm down aggregate)

Typical acceptable Gauged Hot Mix Limecrete for Core bedding
(all quantities batched by volume):-

- 1 part Hydraulic lime (NHL5 St Astier or NHL3.5 Roundtower grey) or Prompt:
- 1 part quicklime (Clogrennane kibbled or powder):
- 2 parts coarse sand (If a silica sand as opposed to a calcareous sand is to be used then substitute 0.5 part for limestone dust).
- 2 parts rounded estuary, river or sea pebble up to 10-18mm in size

Re-laying Masonry

Lime mortar works can be affected by excessive wind, rain, sun or low temperatures.

If these conditions prevail the working areas must be kept moist by spraying and protection using polythene or hessian sheets sprayed with water at regular intervals. Spray hoses can be used for large areas or for damping down hessian sheets but should be used with caution to avoid jet action of water washing out mortar or over saturating a wall. Thus a bottle spray, sprayer back pack or similar is an essential part of the equipment.

No works to be carried out if below 5 degree Celsius temperatures forecast within 48 hours unless temperature control methods such as tented enclosures deployed.

All loose stones are to be laid on a full bed of mortar, spread on a carefully cleaned and wetted upper surface of the underlying masonry. Slate or small stone pinnings may be used to level the stone and all horizontal and vertical joints are to be completely filled with mortar well packed in so that the loadings of the structure are distributed evenly.

Think of mortars as soft beds to provide cushions between stones. Lime does not glue things together or create a hard, impervious skin like cement-based mortars and coatings. Where new stones are to be inserted, allow for “dry packing” joint over with barely wet mortar.

The new mortar joints of the rebuilt stone and brickwork are to match exactly the existing joint depth and are to be struck flush, brushed off diagonally across joint in both directions and sponged off carefully to match exactly the re-pointing works to the remainder of the masonry. Care must be taken to ensure that mortar or grout splashes do not stain the existing masonry faces. See also note below re: beating back of mortar once stiff.

Preparation for Re-pointing and initial build-out

Prepare areas for re-pointing using small hand-held tools and by removing all the very friable mortar saving any small stones (“gallets” or “pinnings”) that come loose for re-use.

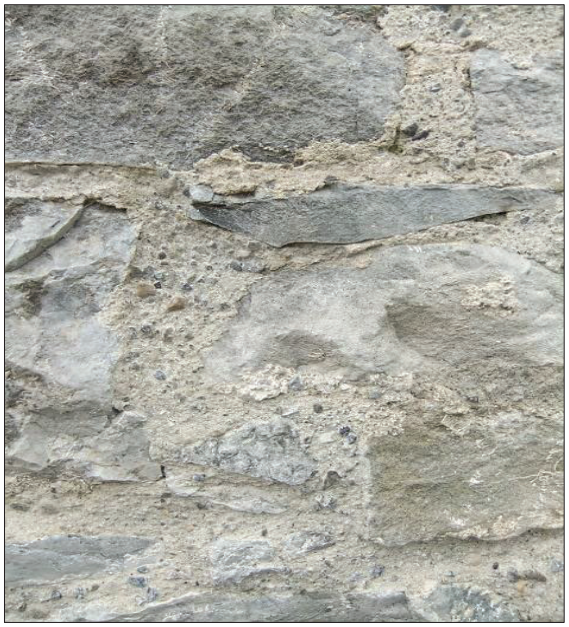
Good preparation is essential for all lime works and a brush is an essential piece of equipment for cleaning out joints, wall surfaces and for brushing pointed joints. Do not use large blobs of mortar to fill in voids or loose areas; build up with pieces of stone. If the voids are large, bed in the small filler stones in the normal way. If smaller then fill void with mortar and then drive in a stone wedging it in tightly to tighten up loose masonry.

Re-Pointing

Carefully rake out joints to depth of twice the joint width. Face of raked out mortar to be cut back square and not sloped or V-shaped. Brush out joints to clear of all debris.

Wet down joints and adjoining masonry to be pointed thoroughly, on dry or windy days spraying may be needed several times and also occasionally during the pointing process and after the work is completed. The wetting is to stop the bed joints from drawing water out of the pointing mortar that would make it dehydrate and fail to set. Lay the pointing mortar on a hawk to a depth equal to the depth of the joint and square off the front edge. Using a pointing iron of similar depth to the joint, cut off thin strips of mortar and offering the hawk up to the joint press well in with the pointing iron.

Make sure the joint is well filled and the front face brushed off lightly once the mortar has become stiffer. Beating back the mortar with a churn brush (as supplied by lime supply companies above) once stiff also assists with compaction of the mortar into the joint and reduction in shrinkage cracks.



Example of flush pointing in stonework beaten back to expose aggregate

Protection & Follow up Work

All finished work must be protected by plastic sheeting or damp hessian sheeting to prevent the joints or coatings from drying out too quickly or conversely becoming saturated

Some slight cracking may occur to the joints and this should be pressed back by hand/churn brush. Brushing up of finished pointing is essential to roughen the finish and clean up drips and splashes from adjoining areas.

All masonry works should be carefully planned such that proper protection can be included or scheduled for the warmer months of the year. Precautions of suspending operations until the temperature reaches 6^0 C on a rising thermometer or 8^0C on a falling thermometer shall be strictly observed. Also frost protection and protection from saturation by rain is essential.

The horizontal surfaces of masonry are particularly vulnerable to saturation and thus frost damage in the weeks immediately following rebuilding/ pointing and should therefore be protected from excesses of water. The vertical elevations can be protected by draping with hessian. Consideration should be given to insulating and /or applying heat to wall faces if cold weather is forecast in the two months during or after masonry works are completed.

Care must also be taken to protect applied work from rapid drying conditions i.e. exposure to direct sunlight or drying winds. In these conditions it should be kept evenly damp for up to 30 days, depending on ambient conditions and the rate of set, by lightly spraying periodically with clean water. In areas exposed to direct sunlight, the possibility of a "greenhouse" effect must be avoided, either by shading the polythene or by substituting woven cloth materials.

Polythene, hessian or other approved sheeting that is used during curing should be arranged to hang clear of the face of the wall in such a way that it does not form a tunnel through which the wind could increase the evaporation of water. The polythene or hessian sheeting must not have intermittent contact with the pointing / render as this may cause a patchy appearance.

Example of appropriate protection to allow Pier to dry out yet not become saturated by rain on upper surfaces. This is relevant only to above tide work

Recommended Reading / useful references

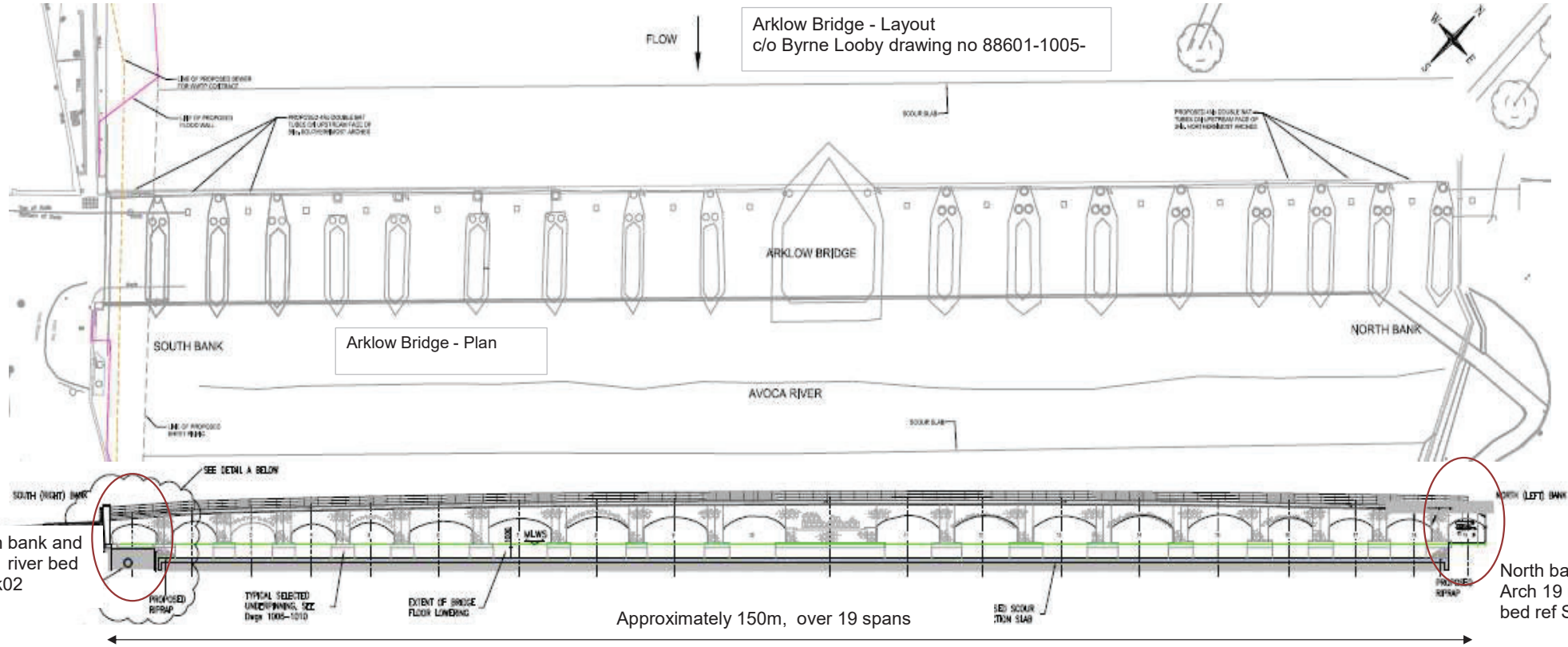
"**Lime Works** - *using lime in traditional and new building"* Patrick McAfee 2010
Commissioned by the Building Limes Forum Ireland
Published by Associated Editions ISBN: 978-1-978-1-906429-08-9

Hot Lime Mortars - HLM Project
Technology Transfer & Applied Research Scotland & Ireland May 2015
available on Building Limes Forum Website www.buildinglimesforumireland.com

4.4 Drawings showing current condition and advised repairs

These 10 sketches are reproduced here at A4 size but are also available at A3

- 18572 Arklow Bridge Sk01-P3 2021-03-15 Key Plan
- 18572 Arklow Bridge Sk02-P2 2021-03-15 South Bank
- 18572 Arklow Bridge Sk03-P2 2021-03-15 Pattress Plates Arches 1-6
- 18572 Arklow Bridge Sk04-P2 2021-03-15 Typical Arch & Cutwater south
- 18572 Arklow Bridge Sk05-P2 2021-03-15 Arches 7-10
- 18572 Arklow Bridge Sk06-P3 2021-03-15 Central Pier
- 18572 Arklow Bridge Sk07-P3 2021-03-15 Typical New works
- 18572 Arklow Bridge Sk08-P2 2021-03-15 Arches 11-15
- 18572 Arklow Bridge Sk09-P2 2021-03-15 Arches 15-19
- 18572 Arklow Bridge Sk10-P2 2021-03-15 North Bank



South bank and Arch1 river bed ref Sk02

North bank and Arch 19 river bed ref Sk10

Span 1 to 10 (south side) ref drg Sk03 through to Sk05

Central Pier ref Sk06

Spans 11 to 19 (north Side) ref Sk07 through to Sk09

Arklow Bridge - overview (east elevation)

Drawing Stage:						Drawn By:	Checked By:	Approved By:	Date:	CORA CONSULTING ENGINEERS									
PRELIMINARY		P3	Issued for inclusion in Structural Report Issue 3	15/03/2021	LE	TB	LE	LE	08/02/2019										
Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name: **Arklow Bridge Conservation Works**			Scale: ~1:500 @A3	Project Number: 18572									
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE														
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title: **Key Plan**			Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.:	Stage:	Revision:		
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY										SK-01	P	3		

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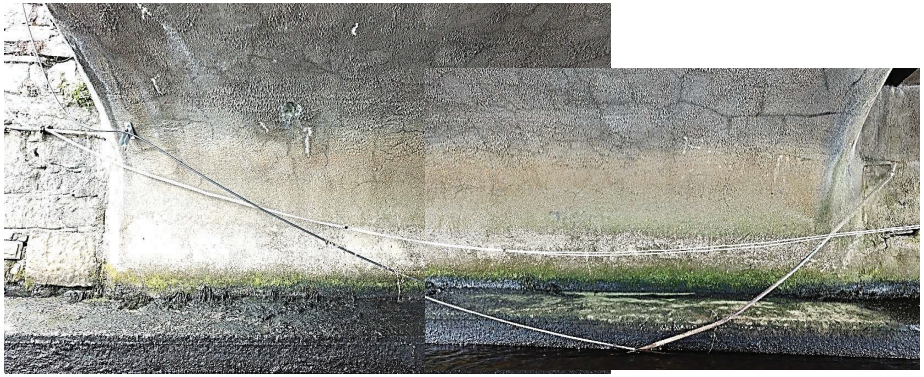

Sequence of photos showing south embankment and various interventions.
The opportunity presents for enhancing earlier stonework, removing vegetation that has the potential to damage the masonry; repointing and re-presenting this south embankment as a strong robust masonry structure.

Note large random shaped stone blocks in river bed at each and every arch.
Most of these will be excavated out of the river bed as part of the river bed lowering scheme.
The opportunity in span 1 and 19 presents itself to reinstate in span 1 above new sewer and retain and

South Embankment and Span No1

South Bank - west, upstream side.
This bank will be altered as part of the process of inserting new Main sewer.

These blocks to the base of the river are likely to be long stones placed point down to form interlocking anti-scour bed. However those excavated 2019 to arches 1-4 were quite shallow and possibly from non original works
Nonetheless this detail should be reinterpreted where arch 1 now becomes filled with new main sewer insertion.
This detail should be reinstated over new sewer at original bed level.

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Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name:	**Arklow Bridge**		Scale:	Project Number:									
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE		**Conservation Works**		NTS	18572									
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title:	**South Bank and**		Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.:	Stage:	Revision:		
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY		**Arch 1 river bed detail**								SK-02	P	2		

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South end of bridge Spans No1 through to No6

Pattress tie plates to arches 1; 3; 5 and 6

Photos c/o Brady Shipman

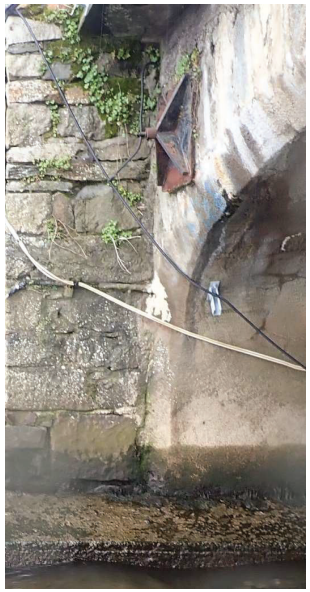
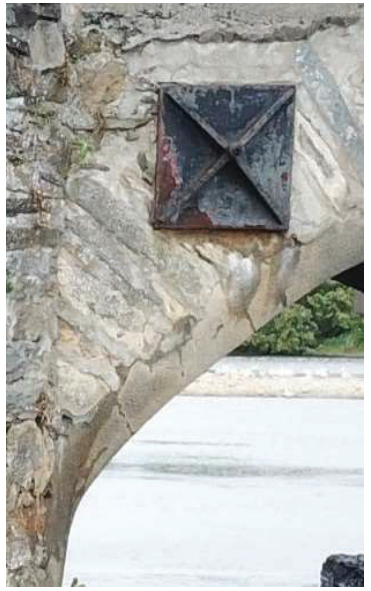


Photo c/o ADCO and John

Pattress plates appear to be of welded steel section rather than Ductile or wrought iron. Works may be coincidental with the 1959 widening works.

Note similar plates are on the upstream side of each of the arches 1; 3; 5 and 6

Condition of these plates needs to be checked and new paint system applied at minimum. The difficulty will be confirming the condition of the hidden faces against the stonework and the bar running through the bridge. Recommendations - gain closer inspection to assess condition and exact make-up. and also any building of masonry behind plates.



Pattress plate

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Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Strucutral Report Issue 2	26/02/2021	LE	Project Name:	**Arklow Bridge**		Scale:	Project Number:									
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Strucutral Report Issue 1	30/09/2019	LE		**Conservation Works**		NTS	18572									
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title:	**Pattress Plates and ties**		Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.:	Stage:	Revision:		
Porject Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY		**Arches 1; 3; 5 and 6**								SK-03	P	2		

Underside of arch concrete sprayed - possible during the masonry works in 1982 or the later the Larson works of 2013, now crazing. All loose and crazed render should be removed to allow close inspection of original fabric and repair by re-packing all empty, leached out mortar joints.

Note lime leaching to some arches in the form of white Calcium carbonate deposits. This signifies loss of fabric from deep within the arch masonry and indicates water penetration through the deck.

Typical downstream detail - significant erosion of pointing from breakwater masonry above concrete apron. This will require re-pointing and re-seating of any loose stones work. Repoint and repair will also allow for a clean up of gunite overspray and give an enhanced visual of the historic masonry.

Typical upstream detail of historic bridge under canopy of newer section - significant erosion of pointing from breakwater. This will require re-pointing and re-seating of any loose stonework.

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PRELIMINARY		P2	Issued for inclusion in Structural Report Issue 3	15/03/2021	LE	TB	LE	LE	08/02/2019									
Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name:	**Arklow Bridge**		Scale:	Project Number:								
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE		**Conservation Works**		NTS	18572								
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title:	**Typical arch and cut water**		Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.:	Stage:	Revision:	
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY		**Condition + repairs required**								SK-04	P	2	

Vegetation growth on masonry requires containment. This growth is a clear indicator that repointing at minimum is required

Mortar erosion from upstream face of masonry requires re-pointing

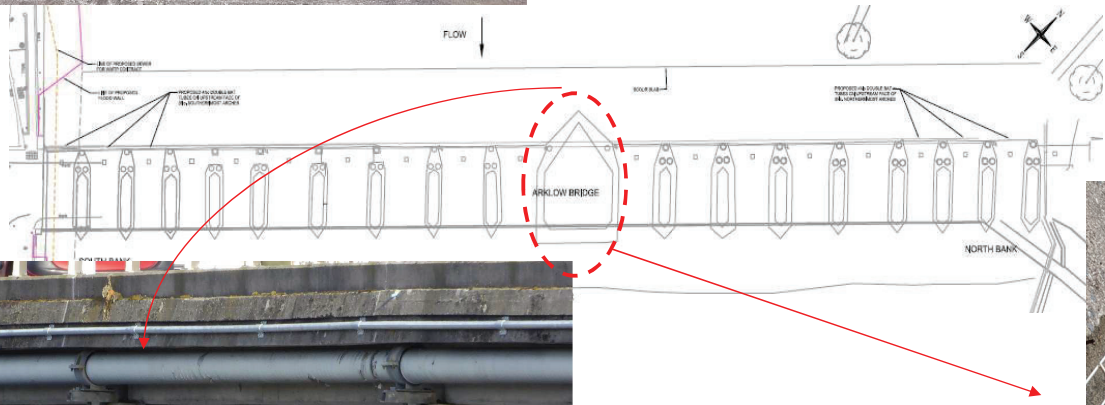
Attrition from floating debris is damaging stonework.
Tree trunks etc catch between newer piers and historic masonry.

Proposed new debris trap upstream should alleviate this issue

Drawing Stage:						Drawn By:	Checked By:	Approved By:	Date:	CORA CONSULTING ENGINEERS									
PRELIMINARY		P2	Issued for inclusion in Structural Report Issue 3	15/03/2021	LE	TB	LE	LE	08/02/2019	Behan House, 10 Lower Mount Street, Dublin 2. D02 HT71 Tel: +353 (0)1 661 1100 e-mail: info@cora.ie web: www.cora.ie									
Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name: **Arklow Bridge Conservation Works**		Scale: NTS	Project Number: 18572										
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE														
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title: **South arches 7-10**		Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.:	Stage:	Revision:			
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY									SK-05	P	2			

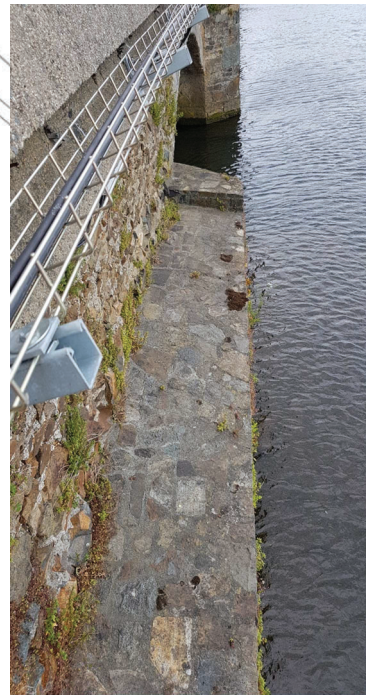
Central Pier - east

Significant vegetation growth including woody stemmed plants.- This extent of vegetation implies that significant erosion to the masonry has occurred and is ongoing. The vegetation needs to be eradicated and masonry repairs including a new capping detail installed. It is likely that a significant depth of capping stone work needs to be carefully recorded, removed and reinstated in mortars as specification



Central Pier - west

Vegetation growth on masonry requires containment.
This growth is a clear indicator that repointing at minimum is required



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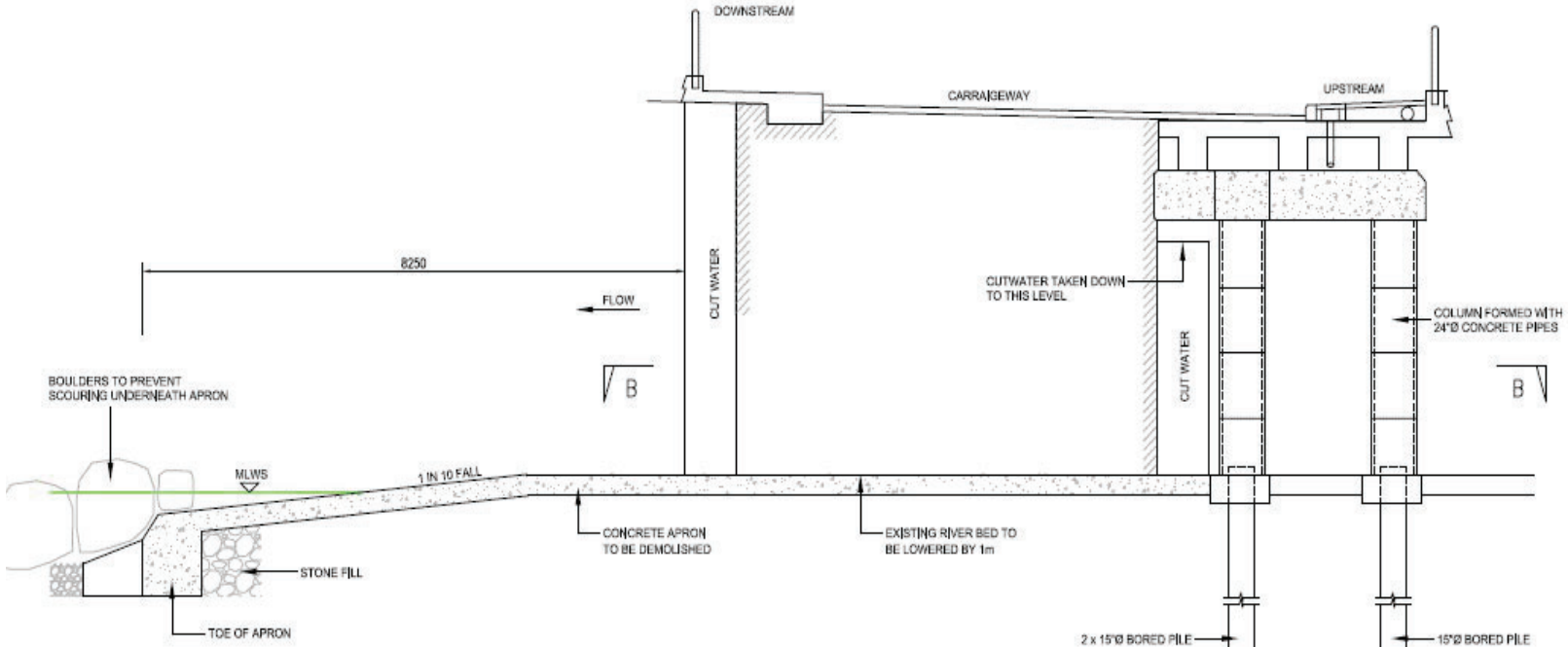
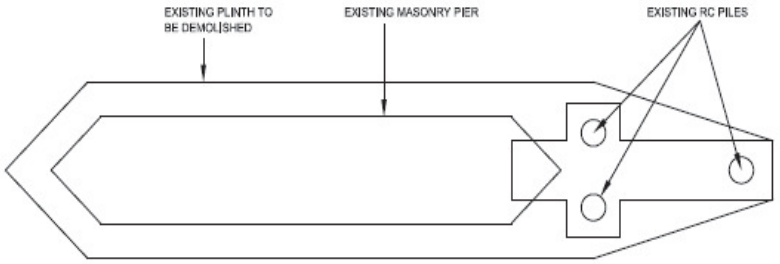
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE														
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title: **Central Pier**			Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.: SK-06	Stage: P	Revision: 3		
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY														



Arklow Bridge - Typical section
c/o Byrne Looby drawing no 88601-1004-



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Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name: **Arklow Bridge Conservation Works**			Scale: NTS	Project Number: 18572									
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE														
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title: **Typical arch**			Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.: SK-07	Stage: P	Revision: 3		
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY														

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Mortar erosion from upstream face of masonry
requires re-pointing

Attrition from floating debris is damaging stonework.
Tree trunks etc catch between newer piers and historic masonry.
New works should include measures to prevent such
The proposed new debris trap upstream should alleviate this issue

Drawing Stage:						Drawn By:	Checked By:	Approved By:	Date:	CORA CONSULTING ENGINEERS									
PRELIMINARY		P2	Issued for inclusion in Structural Report Issue 3	15/03/2021	LE	TB	LE	LE	08/02/2019										
Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name: **Arklow Bridge Conservation Works**			Scale: NTS	Project Number: 18572									
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE														
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title: **North Arches 11-15**			Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.: SK-08	Stage: P	Revision: 2		
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY														

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Mortar washout on tide line. repoint using hydraulic or hot lime and pozzolan mixes. Below tideline, repoint using natural

Underside of arches concrete sprayed - possible during the masonry works in 1982 or the later the Larson works of 2013, now crazing. All loose and crazed render should be removed to allow close inspection of original fabric and repair by re-packing all empty, leached out mortar joints

Down stream debris build up impedes progress of flood waters and should be regularly removed

River bank quay stonework could be greatly enhanced by weed removal and re-seating / pointing

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Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name: **Arklow Bridge Conservation Works**			Scale: NTS	Project Number: 18572									
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE														
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title: **Arches 15-19**			Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.:	Stage:	Revision:		
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY										SK-09	P	2		

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North Bank - west side - view from arch 18

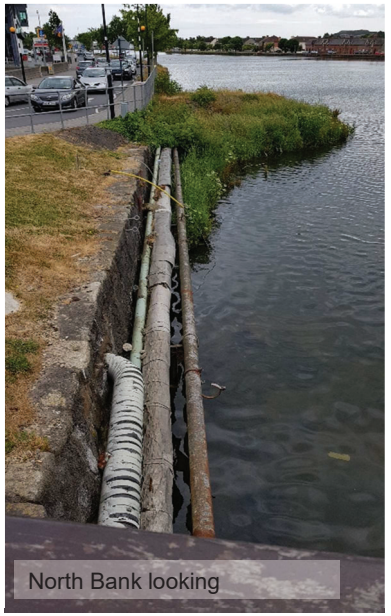
These blocks to the base of the river are likely to be long stones placed point down to form interlocking anti-scour bed. However those excavated 2019 to arches 1-4 were quite shallow and possibly from non original works.
Nonetheless this detail should be retained where possible in the vicinity of arch 19 and repaired as necessary to retain as much of historic form as possible.

North Bank - east side

Arch 19, currently contains services
Reduced works proposed here with none to the river bed under arch

Edge of existing anti-scour apron

North Bank - east



North Bank looking

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Project Details: Arklow Bridge Conservation		P2	Issued for inclusion in Structural Report Issue 2	26/02/2021	LE	Project Name: **Arklow Bridge Conservation Works**			Scale: NTS	Project Number: 18572								
Site Address:	Arklow, Co. Wicklow	P1	Issued for inclusion in Structural Report Issue 1	30/09/2019	LE													
Client:	Wicklow Co. Co. & Dept CH	Draft	Progress print issued for comment and approval	01/07/2019	LE	Drawing Title: **North Bank**			Project:	Originator:	Zone:	Level:	Type:	Discipline:	Drawing No.: SK-10	Stage: P	Revision: 2	
Project Engineer	Byrne Looby	REV. No.	REVISION DESCRIPTION	DATE	ISSUED BY													