Transport for NSW

Monkerai Bridge

Conservation Management Plan

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Transport for NSW

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Prepared by Transport for New South Wales

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Author:	Amie Nicholas
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Executive summary

Description of Item

Monkerai Bridge over the Karuah River is an Old PWD type timber truss bridge (named after the Department of Public works, also called a Bennett truss) which has been assessed as being of State and possibly National significance, and is listed on the State Heritage Register. Located approximately 235 km north of Sydney on a little used unsealed road, Monkerai Bridge is in a remote rural setting. The bridge, approximately 22 km northeast of Dungog was constructed by the NSW Department of Public Works in 1882 and is now under the care and control of Transport for NSW.

Extensive modifications have been made over the years which have damaged both the structural performance and the heritage integrity of the bridge, and the bridge is currently in a state of disrepair. However, some details remain very close to the original design intention, and so the bridge has retained some ability to demonstrate the technical innovation of the Old PWD design. Since April 2004, the bridge has been closed to vehicular traffic, and no longer performs any function for the local community other than carriage of pedestrians. The most recent bridge inspection on file, dated November 2016, records that the bridge is in a very poor and deteriorated condition. The bridge is propped with various additional timber props supported from the ground.

Although the bridge as it currently stands has only limited ability to demonstrate the historical themes of technology and transport, if the bridge were to be repaired with close attention paid to the original design detailing and the original design intent, and if it were to be reopened to traffic, then the bridge will again be able to demonstrate the key technical details of the Old PWD timber truss bridge design, and it therefore will be able to clearly demonstrate the historical themes.

Statement of Significance

Monkerai Bridge is of State significance as the second-oldest surviving timber truss road bridge in New South Wales. It is rare and representative as the only remaining example of a 70' Old PWD truss and as one of only two remaining examples of Old PWD trusses of approximately 150 built.

The excellence in design of the Old PWD truss is historically significant as the first of five stages of timber truss road bridge design in New South Wales, proving and popularising the timber truss as the preferred form of bridge construction for medium span bridges in New South Wales. It is historically significant through its association with the expansion of the State road network, and the contribution of that road system to settlement, development and economic activity.

As an Old PWD truss, Monkerai Bridge has strong associations with William Christopher Bennett, the designer of this truss type. Bennett was recognised as one of the ablest officers in the government service, and held the position of Commissioner and Chief Engineer to the Roads Department of the New South Wales Department of Public Works from 1862 until 1889.

The historical context for the original design and construction of Monkerai Bridge was plentiful New South Wales hardwoods, particularly that large and long old growth timbers were readily available and vast numbers of bridges were being built, but budgets were tight and skilled workmen were few. The New South Wales hardwood timbers used were second to none in Australia, and indeed compared favourably, both for strength and durability, with any timbers in the world. The design is an example of innovative and practical engineering in a time when large and long old growth timbers were readily available and vast numbers of bridges were being built with a tight budget.

Monkerai Bridge fits neatly into the rural landscape, being aesthetically pleasing in scale, proportion and materials used. As a timber truss bridge with its original black and white colour scheme, the trusses in particular are aesthetically distinctive and have landmark qualities. There is some scientific / archaeological potential in the original fabric of the bridge and its setting.

Conservation Policies

Policy 1	Retention of the cultural significance of this bridge a) Cultural significance of this bridge will be protected or enhanced b) Conservation will be in accordance with the principles of the *Burra Charter* c) All relevant staff will be advised and jointly responsible for conservation d) Conservation will be done in collaboration with relevant experts
Policy 2	Adoption, implementation and review of the CMP a) Transport for NSW will adopt this CMP b) Transport for NSW will resource implementation of this CMP c) Transport for NSW will train relevant staff in the use of this CMP d) Transport for NSW will make this CMP available to the public e) Transport for NSW will review this CMP every five years
Policy 3	Use of the bridge a) Transport for NSW will continue to engage with communities about their needs b) This bridge will continue to be used for vehicular traffic c) This bridge will not be used for anything that may cause damage to the bridge d) Transport for NSW will consider arranging for the removal of any existing utilities
Policy 4	Maintenance and repair a) Appropriate ongoing repair and maintenance will be carried out b) Transport for NSW will prepare an Incident Response Plan for this bridge c) This bridge will be maintained to support both functionality and form d) This bridge will be regularly inspected by specialists for structural integrity e) Termites will be inspected for twice a year and treated as necessary f) Any support structures used for repairs will be removed when no longer needed
Policy 5	New work a) Elements will be conserved in accordance with their level of significance b) New works and adaptations may be required to ensure continued operability c) Excellence in design and quality in construction will be provided d) Approvals will be undertaken in accordance with relevant processes
Policy 6	Interpretation a) Cultural significance of this bridge will be effectively communicated b) Interpretation of this bridge will be based on this CMP c) Interpretation will conform to relevant guidelines
Policy 7	Protection and enhancement of visual setting a) Development in the vicinity is to be managed not to have an unacceptable visual impact b) Signage in the vicinity should be kept to a minimum c) Vegetation in the vicinity of the bridge should be kept to a minimum d) Relevant planning and statutory controls must be adhered to for any work in the vicinity
Policy 8	Archival recording a) Records will be managed to ensure permanent retention as State records b) Photographic archival recording will be completed before, during and after any works c) A complete archival recording with 3D mapping will be undertaken of this bridge d) Full documentation will be kept for all methods and materials used during any works e) Representative samples will be retained as a moveable heritage collection

Policy 9	Archaeology a) Relevant Aboriginal stakeholders will be consulted about any proposed impact b) Relevant guidelines and legislation will be adhered to regarding archaeological potential c) Relevant guidelines will be adhered to regarding unexpected finds
Policy 10	Exemptions and Approvals a) Routine maintenance works are identified in Appendix A, Table 1 b) Works requiring further approvals are identified in Appendix A, Table 2
Policy 11	Truss span top chords and principals a) Will be reconstructed to their original design details b) Will be preserved following reconstruction c) Will be replaced before deterioration affects safety or serviceability
Policy 12	Bottom chords and butting blocks a) Will be reconstructed to their original design details strengthened with external steel plates b) Will be preserved following reconstruction and strengthening c) Will be replaced before deterioration affects safety or serviceability
Policy 13	Truss span metal a) Will be reconstructed to their original design details, with slight increase in size as required
Policy 14	Truss span sway braces a) Will be replaced with new sway braces which reflect the form and function of the original
Policy 15	Truss span cross girders a) Secondary cross girders will be reconstructed to their original design details b) Primary cross girders will be replaced in steel to reflect the form and function of the originals
Policy 16	Approach spans a) Will be adapted to allow for modern requirements in a visually recessive manner
Policy 17	Decking a) Will be replaced with new decking to reflect the fabric, function and aesthetic of the original b) Will be maintained to ensure safety of vehicles
Policy 18	Railings a) Will be replaced with a new visually recessive but complying traffic barrier
Policy 19	Piers and abutments a) Piers will be replaced with new piers which reflect the form and function of the original b) Abutments will be replaced with new visually recessive abutments.
Policy 20	Truss span top chords and principals a) Will be reconstructed to their original design details

Contents

Figures

Appendices

1. Introduction

1.1 Purpose and scope

The purpose of this conservation management plan (CMP) is to guide the conservation and management of Monkerai Bridge with a continuing role and use in the life of the local community. This CMP has been informed by, and is consistent with, the Overarching CMP (OCMP), which provides a methodology to address the collective conservation and management of the overall population.[1]

Transport for NSW is responsible for the operation and maintenance of this timber truss bridge. When planning for maintenance and ongoing use, the heritage significance both of this particular bridge and its contribution to the overall population of timber truss bridges must be considered. This CMP identifies the significance of the bridge and provides conservation policies and strategies to ensure its ongoing use.

The CMP:

- Understands the heritage item through investigation of the history of the bridge in its setting, its associations, its aesthetic and technical attributes, its importance to the community, its rarity and representativeness as well as its research potential.
- Provides a statement of significance by analysing documentary and physical evidence.
- Examines constraints and opportunities for conservation, including the requirements of Transport for NSW to maintain the operability and ongoing use of the bridge.
- Develops conservation policies, arising out of the assessment of significance, to ensure the retention of the heritage significance and develops strategies to manage the significance.

1.2 Background

In 2010, Roads and Maritime prepared *Timber Truss Road Bridges – A Strategic Approach to Conservation* (the Strategy). The Strategy detailed a methodology for assessing the conservation suitability and approach to managing the (then) 48 remaining timber truss bridges managed by Roads and Maritime listed on the Roads and Maritime's Section 170 Heritage and Conservation Register (S170). A large proportion of the bridges were also listed on the State Heritage Register (SHR) and some on Local Environment Plans (LEPs). The final version of the Strategy was endorsed by the NSW Heritage Council in August 2012.

After some years of implementation of the Strategy, the list of bridges to be retained under the Strategy was reviewed due to lessons learned with respect to the original design intent of the bridges, the achievable capacity of the strengthened bridges and changing community needs. The updated list was endorsed by the NSW Heritage Council in June 2019.

[1] Roads and Maritime, *NSW Timber Truss Road Bridges Overarching Conservation Management Plan*, February 2018, endorsed by the Heritage Council of NSW on 20 February 2018.

The Strategy requires Transport for NSW to develop conservation planning documentation to set out how individual bridges are to be managed and how the overall heritage values of the retained population will be conserved. Roads and Maritime prepared an Overarching CMP for NSW timber truss road bridges which was endorsed by the NSW Heritage Council in February 2018. The OCMP sets out the overall policy framework so that a consistent approach can be applied to all bridges to be retained. Transport for NSW has committed to the development of a bridge specific CMP for each of the timber truss bridges it manages and intends to retain under the Strategy, which includes this CMP for Monkerai Bridge.

1.3 Overview of Monkerai Bridge

Monkerai Bridge over the Karuah River is an Old PWD type timber truss bridge which has been assessed as being of State significance, and is listed on the State Heritage Register (SHR). Located approximately 22 km northeast of Dungog on a little used unsealed road, Monkerai Bridge is in a remote rural setting. The bridge was constructed by the Department of Public Works in 1882 and is under the care and control of Transport for NSW (TfNSW).

The bridge is approximately 100 m long and 5.5 m wide, consisting of three timber girder approach spans of varying lengths (approximately 8.5 m, 12.2 m and 12.3 m respectively) and three 70' (21.336 m) Old PWD type truss spans. The six spans are supported on five timber trestle piers and two timber abutments. Although the bridge is closed to traffic (and has been since 2004) due to severe deterioration, it would normally carry a single lane of traffic.

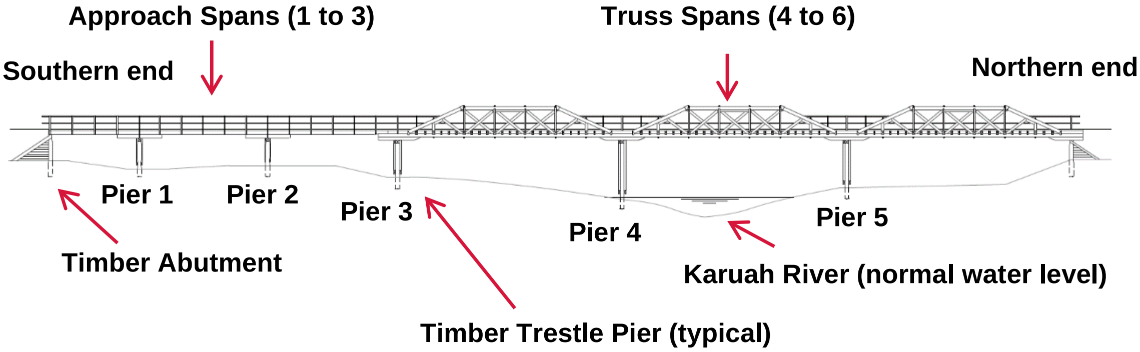

Figure 1-1: Diagram showing general arrangement of Monkerai Bridge.

(source: author)

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Figure 1-2: Photograph of Monkerai Bridge in its setting from distance.

(source: author 2017)

Figure 1-3: Photograph of Monkerai Bridge in its setting from close.

(source: author 2017)

1.3.1 Location and Site Identification

For the purpose of this CMP the place consists of the bridge with its curtilage and a visual setting and context which surrounds and includes the historical crossing.

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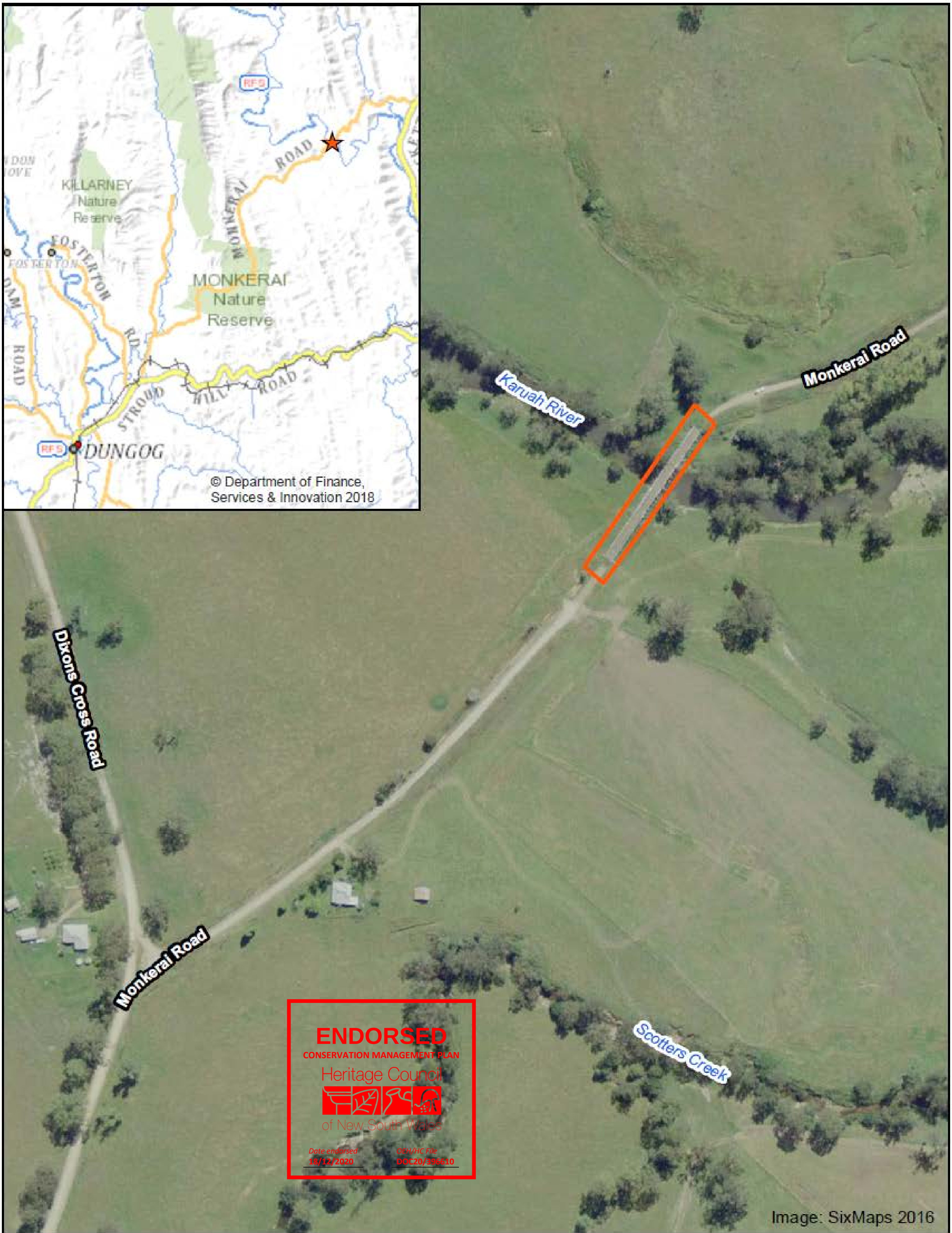

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MONKERAI BRIDGE OVER KARUAH RIVER (SHR 01475)

Legend

State Heritage Register Curtilage

0 25 50 100
Metres

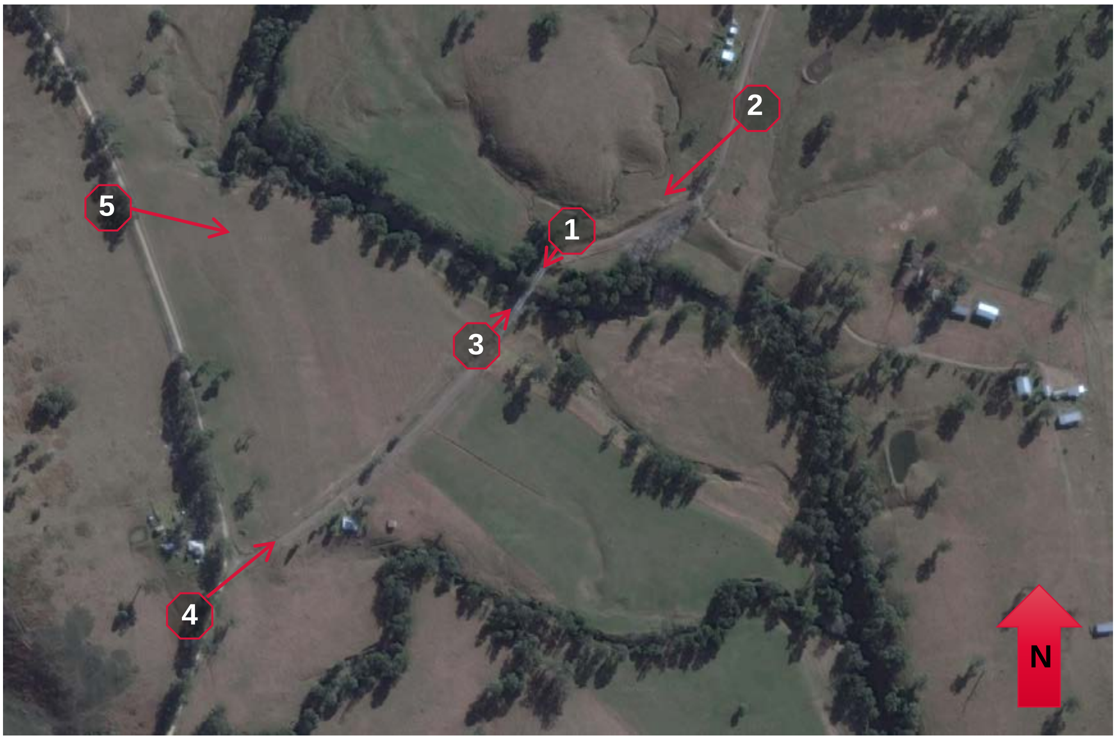
Scale: 1:3,000
Saved: 15/04/2020
GDA 1994 MGA Zone 56
LGA: Mid-Coast

1.3.2 Visual setting and context

Monkerai Bridge is situated on a narrow and unsealed road (closed to traffic) in a rural setting remote from population centres. The landform is largely flat with gentle slopes on the southern side of the river and moderately steep river banks on the northern side of the river. The majority of the surrounding area adjacent to the bridge is rural property with the closest residences located approximately 250 metres to the southeast and 300 metres to the north of the bridge. Vegetation in the local area is comprised of riparian vegetation along the banks of the Karuah River and pasture grasses associated with grazing paddocks, which adjoin the riparian vegetation.[2]

Due to the local topography, vegetation and especially the fact that the bridge is closed, the structure cannot easily be viewed from the northern side, but is best viewed from the southwest. The following pages provide some of the more prominent and important views of the bridge.

Figure 1-4: Aerial View of Bridge with locations from which views are seen.



(source: Google Maps)

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[2] GHD, *Review of Environmental Factors, Rehabilitation Works on Monkerai Bridge*, Draft July 2003, p 6.

Figure 1-5: View 1 of Bridge approaching from the north close to bridge.

(source: author 2012)

Figure 1-6: View 2 of Bridge approaching from the north 250m from bridge

(source: author 2012)

Figure 1-7: View 3 of Bridge approaching from the south close to bridge.

(source: author 2012)

Figure 1-8: View 4 of Bridge approaching from the south at start of detour.

(source: author 2017)

Figure 1-9: View 5 of Bridge viewed from West on detour, Dixons Crossing.

(source: author 2017)

As is indicated in Figure 1.2, the bridge is approximately 100m in length consisting of six spans. The main spans are 70’ (21m) Old PWD type timber truss spans and the three approach spans are timber girder spans. The bridge has a total width of approximately 5.5m and was designed to carry a single lane of traffic. The six spans are supported on timber trestle piers and timber abutments. Due to the poor condition of the bridge, a large number of temporary props have been added. A comprehensive investigation and identification of the existing fabric is given below in Section 3.2.

1.3.3 The curtilage

The heritage curtilage is defined as the area of land surrounding an item of heritage significance which is essential for retaining and interpreting its heritage significance. A curtilage is used to establish the boundaries of a zone worthy of special protection, and should contain all elements contributing to the heritage significance, conservation and interpretation of a heritage item.[3]

The heritage curtilage for bridges listed on the SHR managed by Roads and Maritime is set as a horizontal buffer of five metres from the outward side and termination of the bridge deck. The curtilage also extends in space above and below deck level. Monkerai Bridge is listed on the SHR, and this curtilage is contiguous with the SHR listing boundary. This curtilage remains suitable.

The curtilage for Monkerai Bridge is shown on page 11.

[3] Heritage Office, Dept. Urban Affairs and Planning, *Heritage Curtilages*, Harley & Jones, 1996, pp 1-5.

1.3.4 Statutory Listings

Table 1-1: Summary statutory listing and site identification information

State Heritage Register name and number	Monkerai Bridge over Karuah River SHR 01475
Transport for NSW s170 number	4300133
Local Environmental Plan (LEP) details	Great Lakes LEP item I84
Alternate / locally used names / descriptive location	Bridge over Karuah River at Wilkinson's
Transport for NSW Bridge number	B01477
Road name	Monkerai Road
Coordinates [centre point] – latitude / longitude	Lat: -32.2834533933 Long: 151.8771582840
Local Government Area	Mid Coast Council
Transport for NSW Region	Hunter Region

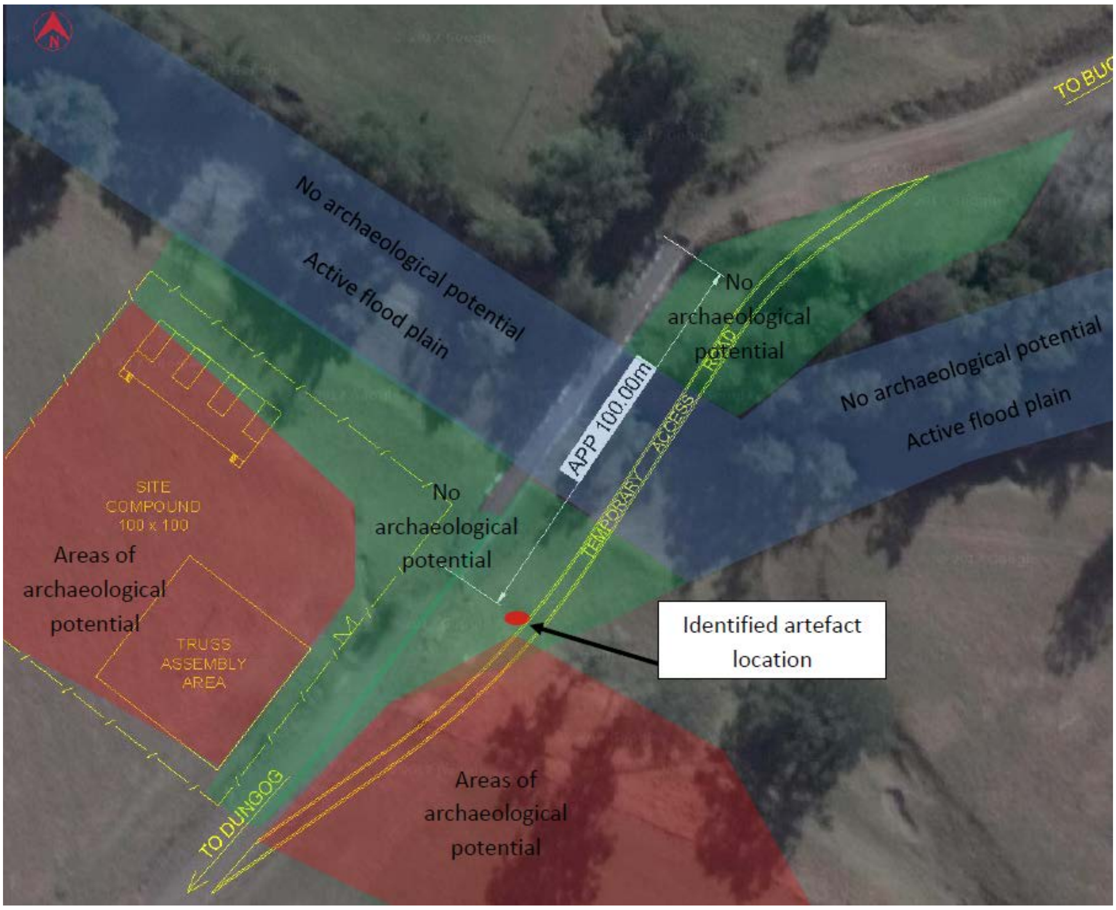
1.3.5 Archaeological elements

No historical evidence has been found regarding the presence of any earlier bridges or punts at this location. During the site inspection no physical evidence of any archaeological remains of earlier crossings could be seen. The river in this location is not usually deep and can easily be forded and this is probably how the river was crossed prior to construction of the Bridge.

Roads and Maritime recently engaged Kelleher Nightingale Consulting Pty Ltd to prepare an Aboriginal archaeological survey report to inform the Review of Environmental Factors (REF) for the site.[4] This assessment was prepared in accordance with the Stage 2 requirements of the Roads and Maritime Procedure for Aboriginal Cultural Heritage Consultation and Investigation (PACHCI) and the Office of Environment and Heritage Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales.[5] The archaeological assessment was conducted in consultation with Karuah Local Aboriginal Land Council (LALC). No Native Title holders/claimants are currently registered for the study area. One Aboriginal archaeological site (isolated artefact) was identified and assessed as displaying low scientific significance.[6] Two areas of potential archaeological deposit (PAD) were identified within the study area and were considered to display moderate archaeological potential. These are shown in Figure 1-10 below.

[4] Kelleher Nightingale Consulting, Bridge over Karuah River at Monkerai Bridge, capacity upgrade project Aboriginal Archaeological Survey Report Stage 2 PACHCI, May 2017.
[5] Roads and Maritime Procedure for Aboriginal Cultural Heritage Consultation and Investigation, Office of Environment and Heritage Code of Practice for Archaeological Investigation of Aboriginal Objects in NSW.
[6] Because this artefact was only recently discovered, it has not yet been formally assessed or described.

Figure 1-10: Map showing Archaeological Potential



(source: Kelleher Nightingale Consulting)

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1.4 Methodology and structure

The OCMP provides a methodology to address collective management, so that a representative population of New South Wales timber truss road bridges is conserved and managed into the future, continuing to have a role and use in the life of communities. The methodology and structure of this bridge specific CMP is guided by the OCMP. The primary purpose of a CMP is to establish policies which will guide the future care and development of a place.[7] This CMP has been prepared according to the methodology recommended in *Assessing Heritage Significance*, and is consistent with the guidelines set out in the Australia ICOMOS Burra Charter, 2013 *(Burra Charter)* and in the Conservation Plan.[8]

Cultural significance is defined in the *Burra Charter* as aesthetic, historic, scientific, social or spiritual value for past, present or future generations.[9] In order to conserve significance, it is necessary to understand why the bridge is significant. Identifying the heritage significance of an item relies on understanding and analysing documentary and physical evidence.

A site inspection was undertaken on Tuesday 9th May 2017 to examine the current condition and integrity of the bridge. Historical research was undertaken making use of previous reports where applicable, but also undertaking further research through the Transport for NSW archives and the online resources of the State and National libraries.

The format and structure of this report follows the Transport for NSW template, developed in conjunction with Heritage NSW, Department of Premier and Cabinet, and includes the following:

- A historical investigation seeking to understand the bridge and its setting (chapter 2)
- An investigation of the documentary and physical evidence from the bridge (chapter 3)
- An assessment and statement of significance considering the documentary and physical evidence against the seven criteria outlined in the NSW Heritage Manual (chapter 4)
- An analysis of the constraints and opportunities arising from both the heritage significance of the bridge and the operational requirements for the bridge (chapter 5)
- An investigation into a range of conservation options, taking into account the current condition, the ongoing maintenance requirements, other requirements imposed by external factors (such as legislation) and a range of strategies to provide for the safe ongoing use of the bridge while maintaining or enhancing the heritage value (chapter 6)
- Conservation policies for the bridge (chapter 7)

1.5 Contributors

This CMP has been prepared by Amie Nicholas, Roads and Maritime, Chartered Heritage and Conservation Engineer (Structural), BE, Grad Dip (PM), M.E., M.Herit.Cons., FIEAust, CPEng.

It has been peer reviewed by Tony Brassil, Senior Heritage Consultant of Extent Heritage.

[7] James Semple Kerr, Conservation Plan, 7th edition, National Trust of Australia (NSW), January 2013, p 22.
[8] Assessing Heritage Significance, NSW Heritage Manual, NSW Heritage Office, 2001; Burra Charter, 2013; James Semple Kerr, Conservation Plan, 7th edition, National Trust of Australia (NSW), January 2013.
[9] The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance, 2013

1.6 Terminology

The terminology in this report is consistent with the definitions given in the *Burra Charter 2013* (copied in full below) with bridge specific terminology as defined in 1.6.2 and Figure 1-11 to Figure 1-13.

1.6.1 Burra Charter definitions

Place *means a geographically defined area. It may include elements, objects, spaces and views. Place may have tangible and intangible dimensions.*

Cultural significance *means aesthetic, historic, scientific, social or spiritual value for past, present or future generations. Cultural significance is embodied in the place itself, its fabric, setting, use, associations, meanings, records, related places and related objects. Places may have a range of values for different individuals or groups.*

Fabric *means all the physical material of the place including elements, fixtures, contents and objects.*

Conservation *means all the processes of looking after a place so as to retain its cultural significance.*

Maintenance *means the continuous protective care of a place, and its setting. Maintenance is to be distinguished from repair which involves restoration or reconstruction.*

Preservation *means maintaining a place in its existing state and retarding deterioration.*

Restoration *means returning a place to a known earlier state by removing accretions or by reassembling existing elements without the introduction of new material.*

Reconstruction *means returning a place to a known earlier state and is distinguished from restoration by the introduction of new material.*

Adaptation *means changing a place to suit the existing use or a proposed use.*

Use *means the functions of a place, including the activities and traditional and customary practices that may occur at the place or are dependent on the place.*

Compatible use *means a use which respects the cultural significance of a place. Such a use involves no, or minimal, impact on cultural significance.*

Setting *means the immediate and extended environment of a place that is part of or contributes to its cultural significance and distinctive character.*

Related place *means a place that contributes to the cultural significance of another place.*

Related object *means an object that contributes to the cultural significance of a place but is not at the place.*

Associations *mean the connections that exist between people and a place.*

Meanings *denote what a place signifies, indicates, evokes or expresses to people.*

Interpretation *means all the ways of presenting the cultural significance of a place.*

1.6.2 Bridge specific definitions

Abutment means the structure on which the ends of the outer spans are supported.

Bottom chord means the lower horizontal member of the truss (Figure 1-11).

Butting block means the timber component used to transfer the loads from the principals to the bottom chords (Figure 1-11).

Cast iron shoe means the cast iron component which connects the ends of the truss principals to top and bottom chords (Figure 1-11).

Corbel means a timber member used to increase the load bearing length of timber girders over the pier so that the girder can still take load after decay has begun (as it generally does) at the ends.

Cross girder means a transverse bending member spanning between the upstream truss and the downstream truss which supports the deck. Primary cross girders are of larger dimensions and are located at panel points. Secondary cross girders are located between panel points.

Deck means the components of the bridge which directly support vehicles (Figure 1-13).

Diagonal means a truss member placed at an angle, excluding principals (Figure 1-11).

Fish plate means a metal plate covering joints in a laminated timber bottom chord.

Girder means a longitudinal member spanning between piers and supporting a deck.

Laminate means a single timber component which forms part of a laminated timber member.

Laminated means three or more rows of parallel components are joined together (by glue, bolts or stressed strand) to form a single member which is longer than any of the individual components.

Panel means the area between the panel points (or main joints) in a truss (for example, the truss of Monkerai Bridge shown in Figure 1-11 consists of seven panels of varying lengths).

Panel point means the locations of the intersections of the main members in a truss.

Pier means a support for the adjacent ends of two bridge spans, and often consists of piles with a top supporting member (headstock) and various horizontal and diagonal bracings.

Pile means a vertical or inclined member driven deep into the ground to support a bridge.

Principal means the primary end (diagonal) timber member in a truss (Figure 1-11).

Railing means the timber posts and rails provided for delineation for vehicles and prevention of accidental falls from the bridge for pedestrians and animals using the crossing.

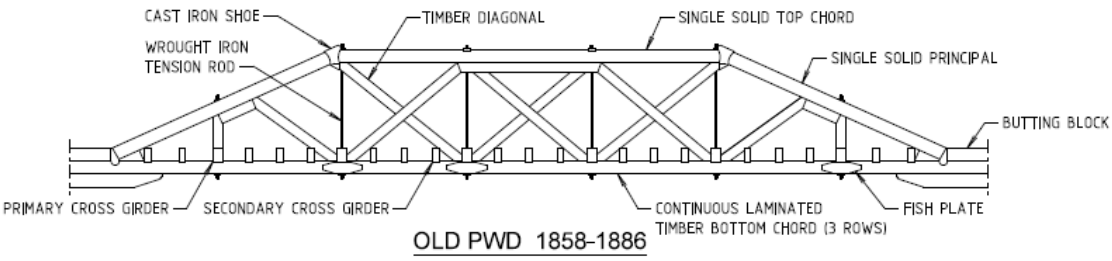
Sway brace means a member located outside the truss extending between the top chord and a cross girder to resist sway of the truss and to provide lateral support to the top chord.

Tension rod means a vertical metal bar connecting the top and bottom chords of a truss .

Top chord means the upper horizontal member of a truss (Figure 1-11).

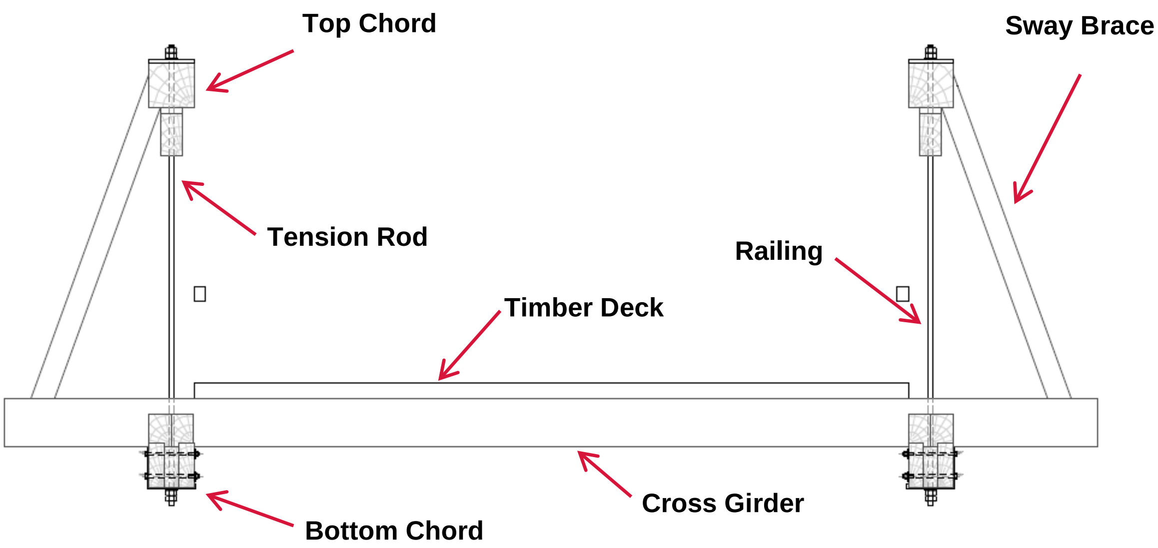
Truss means a special class of structure in which members are connected at joints in a manner that permits rotation so that the individual members can only carry either tension or compression.

Figure 1-11: Diagram showing Old PWD truss terminology from elevation.



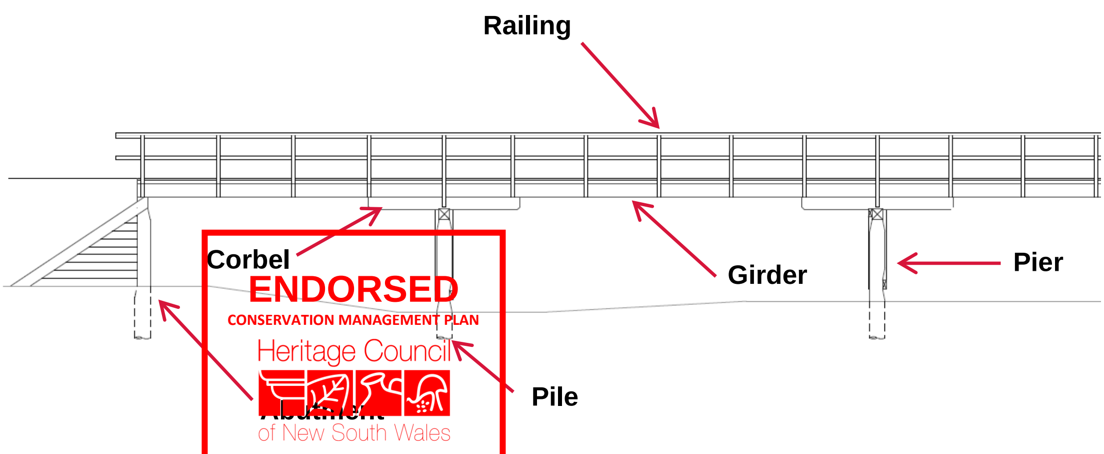
(source: author)

Figure 1-12: Diagram showing Old PWD truss terminology from section.



(source: author)

Figure 1-13: Diagram showing approach span terminology from elevation.



(source: author)

2. Historical context

2.1 History of timber truss bridge design in New South Wales

For more information on local hardwood timbers, the early timber industry in New South Wales and early timber bridges including the development of the truss, see the OCMP.

Experiments made at the foundry of P.N. Russell & Co. in 1860 showed how much tougher the New South Wales ironbark is when compared to Baltic or American timber. The conclusion made was that whatever span had been possible with timber in other countries could certainly be imitated, if not surpassed, in New South Wales. The New South Wales Government therefore made considerable use of hardwood timber for public infrastructure, as well as for export. By the early 1900s, the rapid disappearance of hardwoods was reported due to the recognition of its value by the commercial world of Europe, South Africa, and the East.

Between 1856 and 1936, over 400 timber truss road bridges were built in NSW with this extraordinary local timber. Five exceptional engineers working for the New South Wales Department of Public Works (PWD) applied their sound engineering principles to design these elegant and durable timber truss bridges, some of which continue to carry vehicles today that are larger and heavier and faster than the original designers could possibly have imagined. The vast majority of these bridges can be divided into five types:

1) Old PWD trusses designed by William Christopher Bennett, 1824-1889, Figure 2-1(1)

2) McDonald trusses designed by John Alexander McDonald, 1856-1930, Figure 2-1(2)

3) Allan trusses designed by Percy Allan, 1861-1930, Figure 2-1(3)

4) De Burgh trusses designed by Ernest Macartney de Burgh, 1863-1929, Figure 2-1(4)

5) Dare trusses designed by Henry Harvey Dare, 1867-1949, Figure 2-1(5)

Figure 2-1: The timber truss bridge engineers, Bennett, McDonald, Allan, de Burgh and Dare

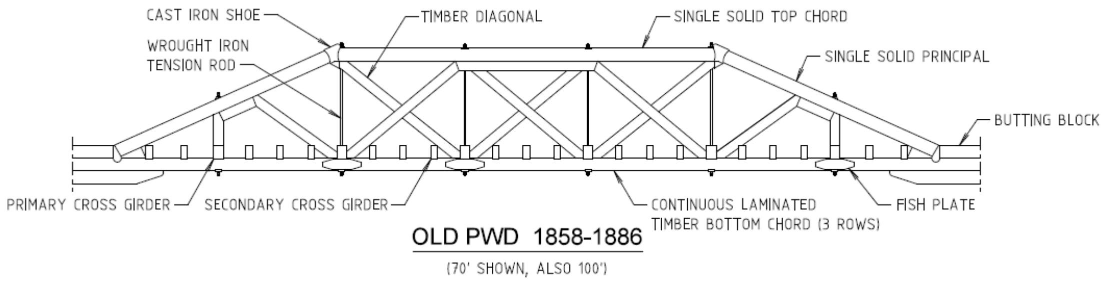
Sources 1 & 4: MBK, Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW, 1998, pp 23, 37; 2: "Pix from the past", Gisborne Photo News, No. 239, 22 May 1974, p 56; 3: "Mr Percy Allan, Noted Engineer's Death", The SMH, Thursday 8 May 1930, p 12; 5: Engineering Heritage, Sydney http://www.engheritage-sydney.org.au/PDFs/Darlington.pm.pdf.

The earlier trusses made use of the vast resource of large, long, strong and durable New South Wales hardwoods. As the unique New South Wales hardwoods became known around the world, so much of it was exported that these earlier types of timber truss bridges could no longer be built as the timber was no longer available. The later truss designs limited the sizes of the timbers to smaller shorter sections which were still readily available.

Old PWD trusses (also called Bennett trusses)

Approximately 150 Old PWD type timber truss bridges were built between 1858 and 1886. The Old PWD trusses designed by Bennett are examples of innovative and practical engineering in a time when large long timbers were readily available and vast numbers of bridges were being built, but budgets were tight and skilled workmen were few. The Old PWD trusses were not designed as permanent structures because the required routes were very likely to be diverted by circumstances impossible to anticipate. For these reasons, any deteriorated timbers are difficult to replace so the bridges tend to have been heavily modified.

Figure 2-2: Annotated diagram of the Old PWD truss design

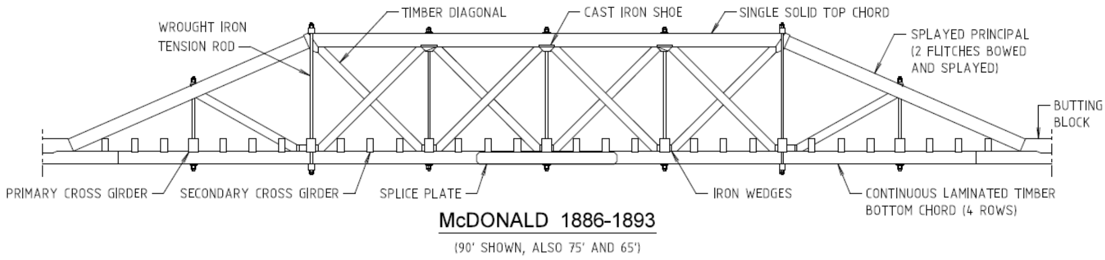


Source: Drawn by Jack Pulczynski for Amie Nicholas 2017.

McDonald trusses

Approximately 90 McDonald type timber truss bridges were built between 18886 and 1893. The historical context which drove the design of the McDonald truss is similar to the Old PWD truss as large, long, quality hardwoods were still plentiful and permanent bridges were not considered economical. The changes in design stem from the growing knowledge of timber as a structural material due to extensive testing at the University of Sydney in 1886, and also the increasing heavy vehicle loads. Again, due to the very large timbers included and the fact that they were not intended as permanent structures, deteriorated timbers are very difficult to replace and remaining examples of this type of truss tends to have been heavily modified.

Figure 2-3: Annotated diagram of the McDonald truss design

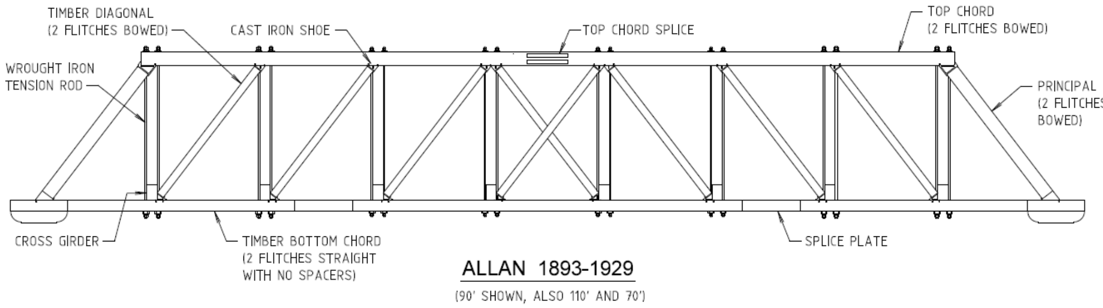


Source: Drawn by Jack Pulczynski for Amie Nicholas 2017.

Allan trusses

Approximately 100 Allan type timber truss bridges were built between 1893 and 1929. The historical context which drove the design of the Allan truss was the increasing difficulty in obtaining large timbers. Allan introduced two important innovations. The first was the detailing of timbers to enable the replacement of deteriorated timber, giving his timber bridges the same life expectancy as metal bridges. The second was his splice connection in the bottom chord which was stronger than previous bottom chord connections. Many Allan and Dare truss bridges were constructed to replace Old PWD or McDonald trusses, sometimes reusing the original foundations if those foundations were constructed in iron or masonry.

Figure 2-4: Annotated diagram of the Allan truss design

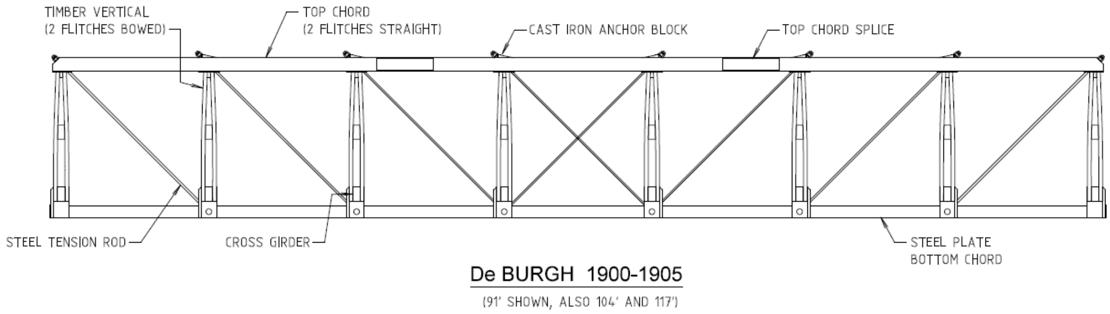


Source: Drawn by Jack Pulczynski for Amie Nicholas 2017.

De Burgh trusses

Approximately 20 de Burgh type timber truss bridges were built between 1900 and 1905. The historical context which drove the design of the de Burgh truss was that materials other than timber had become increasingly available and economical. The de Burgh truss includes the greatest variety of materials found in any of the timber truss bridges, with de Burgh using each material to its best advantage. The result was a stiffer and stronger truss, so that de Burgh achieved the longest span (50m) timber truss bridge in NSW.

Figure 2-5: Annotated diagram of the de Burgh truss design

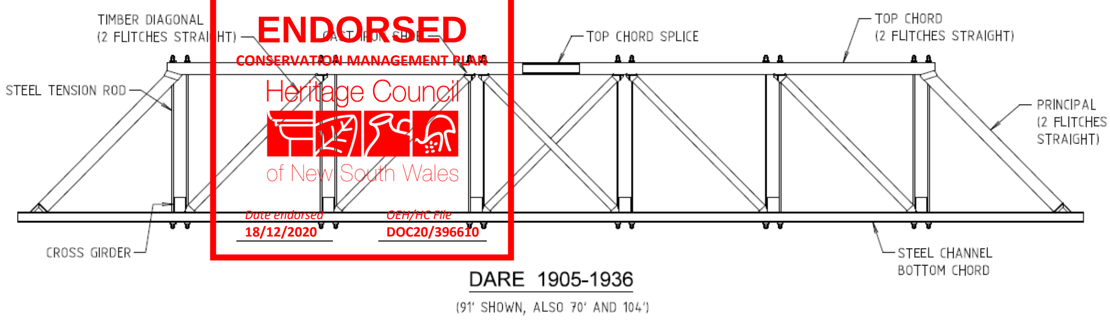


Source: Drawn by Jack Pulczynski for Amie Nicholas 2017.

Dare trusses

Approximately 40 Dare type timber truss bridges were built between 1905 and 1936. The Dare truss was designed to combine the best aspects from the de Burgh and Allan trusses while avoiding the primary problems with each. It has the simplest geometry and allows the easiest replacement of individual timbers.

Figure 2-6: Annotated diagram of the Dare truss design



Source: Drawn by Jack Pulczynski for Amie Nicholas 2017.

2.2 History of the Old PWD truss

2.2.1 Review of the Old PWD design

The Old PWD design prepared by Bennett is the most misunderstood of all the timber truss bridge designs. In 1893 the Old PWD and McDonald trusses were superseded by Allan trusses. Current entries on the State Heritage Inventory for Allan trusses express the widely held view that,

> *"Allan trusses were the first truly scientifically engineered timber truss bridges, and incorporate American design ideas for the first time. This is a reflection of the changing mindset of the NSW people, who were slowly accepting that American ideas could be as good as or better than European ones."* [10]

In his recent paper, Rex Glencross-Grant states that Allan trusses are,

> *"… a far cry from the earlier, stockier, high-maintenance versions that were inherited from British / European designs… such innovative local design was a symbolic way of releasing the restraining shackles of the colonial past and the growth of a nation."* [11]

These ideas were first recorded in 1985 by Don Fraser, who also contributed to the 1998 heritage study of timber truss bridges, which formed the basis of many other documents.[12] Fraser writes:

> *Bridge engineering in New South Wales from 1850 to 1915 had two eras of dominant technologies, British 1850-90 and American post-1890. New South Wales was a British colony and all its early engineers were educated in Britain and gained experience there or in Europe. Therefore, when they exercised those skills in New South Wales, the results were direct copies of and adaptations of British / European technology. This situation coincided with the long terms of office of the colony's two senior engineers John Whitton and William C. Bennett. Nearly all bridges constructed under their control were of British / European origin. There were some examples of American technology such as the 1880 Whipple trusses at Nowra and the first Hawkesbury River railway bridge of 1889 but the intrusion was unwelcomed. However, the merits of, and in some cases the superiority of, American bridge technology was known to the assistant engineers such as Henry Deane, Percy Allan, E.M. de Burgh and Harvey Dare, so when Whitton retired and Bennett died in office, an immediate change-over to American style bridges took place, particularly in the adoption of trusses for large span bridges... Prior to this "Americanisation" of colonial bridge engineering, the accumulated evidence points to a British colony adopting and adapting British / European technology. The new trusses of the 1860s were clearly derived from Palladio's ideas through William C. Bennett's earlier work with the Colonial Architects Office ... Bennett makes it clear that American technology had not yet arrived when he said in his 1865 Report, "for spans exceeding 100 feet, a design on the principal of the McCallum truss, so extensively used with the softer and lighter timber in the United States, has been under consideration for some time and will be applied when the opportunity offers".* [13]

Again, the 1998 MBK report states,

[10] SHI listing for Charleyong Bridge over Mongarlowe River from Heritage Division website (accessed 28/04/17): http://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=4300172
[11] Rex Glencross-Grant, 'The evolution of large-truss road bridges in NSW, Australia', *Proceedings of the Institution of Civil Engineers*, Engineering History and Heritage, Vol 165, May 2012, Issue EH2, p 99.
[12] MBK, *Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW*, 1998, p 11.
[13] D.J. Fraser, Timber Bridges of New South Wales, 1985, pp 93 & 95.

> *"… the evolution of timber truss road bridges in New South Wales from 1860 to 1905 saw a change from traditional, virtually non-scientific, British and European structures to scientifically engineered structures based on developments in America."* [14]

The explanatory notes to the *Burra Charter* state that, "understanding of cultural significance may change as a result of new information" (Article 1.2) and that, "the results of studies should be up to date, regularly reviewed and revised as necessary" (Article 26.1). Clearly then, "Statements of significance and policy should be kept up to date by regular review and revision as necessary" (Article 26.2). The Burra Charter Process flowchart also makes it clear that the process is iterative, parts of it may need to be repeated, and further research and consultation may be necessary.

The three primary areas of research that need to be explored can be summarised as follows:

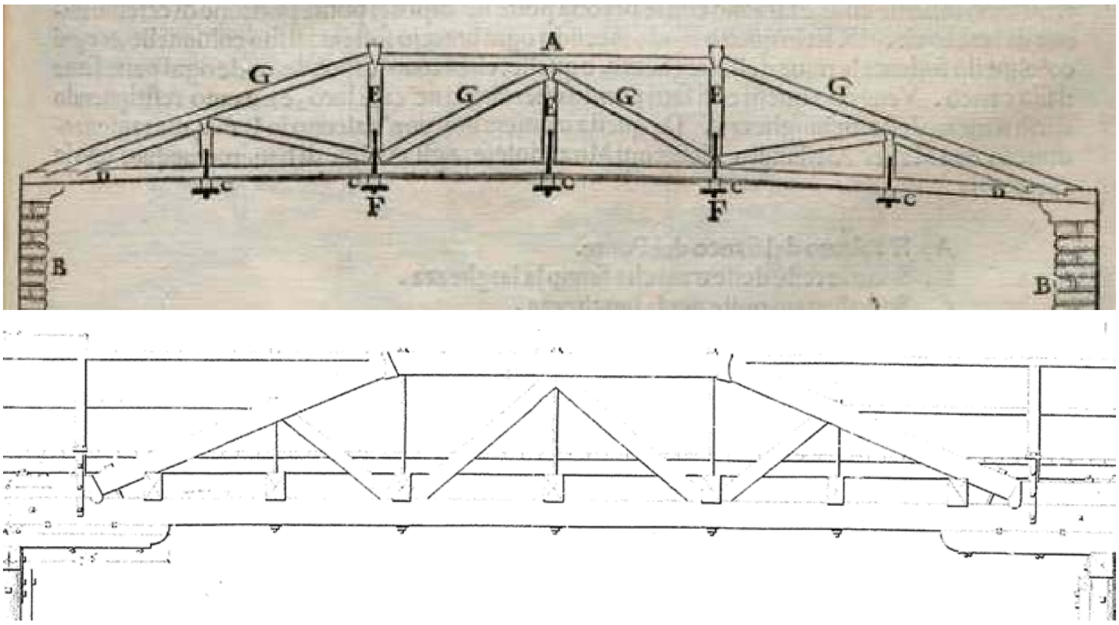
- Were Old PWD timber truss bridges designed before or after the introduction of American ideas and timber truss bridge technology into NSW?
- Were Old PWD timber truss bridges scientifically engineered (ie. designed by calculations for certain capacities) or were they simply adapted from Palladio's works of the 1500s? [15]
- Were Old PWD timber truss bridges designed as stockier bridges made of very large cross-sections and long lengths of timber due to ignorance of other options, or another reason?

Firstly, were Old PWD timber truss bridges designed before or after the introduction of American ideas and timber truss bridge technology into NSW? A cursory glance at Figure 2-7 is enough to discern the similarities between one of the very first timber truss bridges designed by Bennett in the 1860s and Palladio's design recorded in 1570. Both have a total of six bays, with a similar geometry of members. Even here, however, there are significant differences in that Bennett uses iron for the vertical tension members (an American innovation) whereas Palladio uses timber, and Bennett has the cross girders bearing on the bottom chord whereas Palladio has the cross girders hung beneath the bottom chord. Bennett also has iron castings at member ends for connections.

[14] MBK, *Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW*, 1998, p 18.

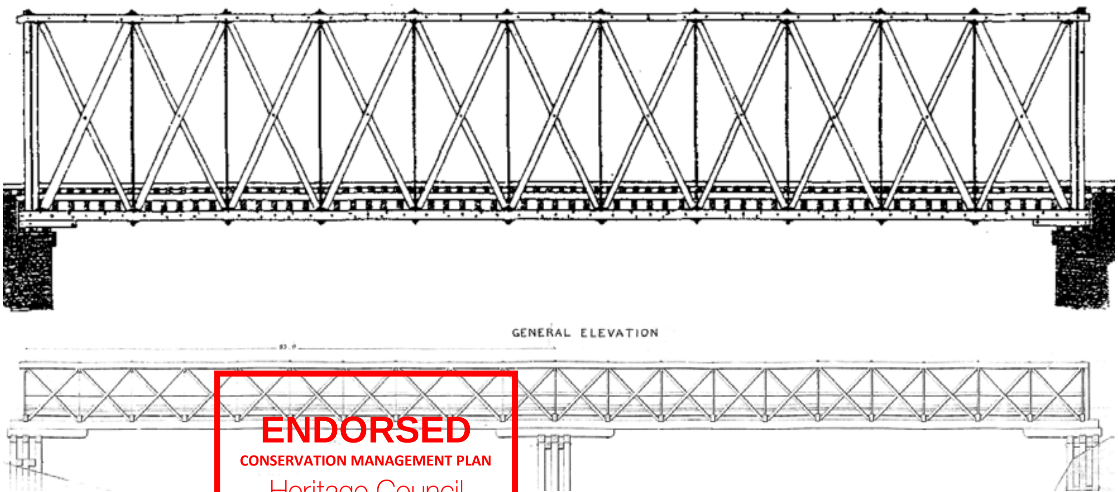
[15] As noted in the Overarching CMP, development of the truss was slow. In the fifteenth century, Leonardo da Vinci analysed the forces in triangulated structures, and produced a design for a timber truss bridge. A century later, Palladio published *The Four Books of Architecture*, in which two timber truss bridges were illustrated. Until the 19th Century, design was purely intuitive, based on experience. Because the Old PWD (or Bennett) truss has visual similarities with Palladio's work, some have come to the conclusion that Bennett's design was not scientific (based on calculations) like the very early European trusses.

Figure 2-7: Palladio's 1570 Truss (above) & Bennett's 1860 Murrurundi Bridge design (below).[16]



However, before the conclusion is drawn that Bennett was shackled to European technology, a cursory glance at Figure 2-8 is enough to discern that another of the very first timber truss bridges designed by Bennett even earlier in 1858 is a clear example of an American Howe truss. Howe trusses were invented and patented by American William Howe in 1840. They consist of heavy timber chords intersecting diagonal braces and vertical end posts. The most critical innovation in the Howe Truss was the use of wrought iron verticals with threaded ends instead of timber.[17]

Figure 2-8: American Howe Truss 1840 (below) & Bennett's 1858 Vacy Bridge (below).[18]



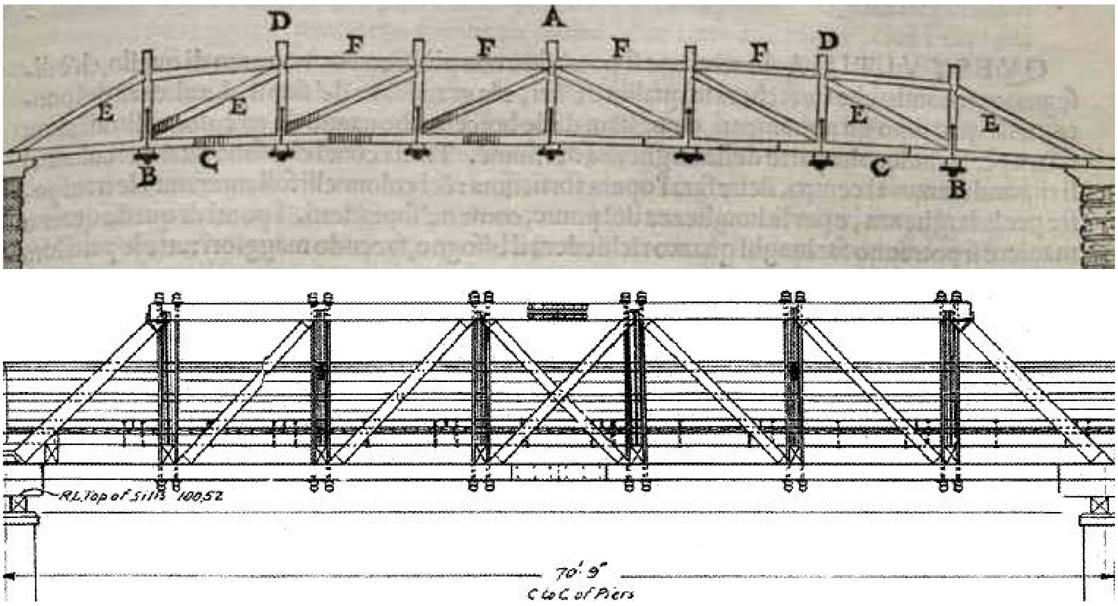
It is clear from this very [illegible]ation that Fraser was incorrect to conclude that Bennett meant in his 1865 report that American technology had not yet arrived in New South Wales. On the contrary, it is clear that Bennett was aware, not only of the technology and the design details, but also of the differences between the softer and lighter American timber and the local

[16] Source: Palladio, The Four Books of Architecture, 1570, book 3, p 15.; Roads and Maritime CARMS plans.
[17] Jeff Brown, 'The Howe Truss: From Timber to Iron', *Civil Engineering*, June 2012, p 41.
[18] Source: Gasparini 'American Truss Bridge Connections', 1997, p 123; Roads and Maritime CARMS plans.

timber used in New South Wales for bridge building, which was more susceptible to warping when sawn.

It is also interesting to note, as the 1987 timber truss bridge maintenance handbook does, the similarities between another of Palladio's trusses and the Allan truss, clearly demonstrating that the innovations and excellence in design of a bridge have more to do with the details than the shape.[19]

Figure 2-9: Palladio's 1570 Truss (above) and standard 70' Allan truss design (below).[20]



Secondly, were Old PWD trusses scientifically engineered (ie. designed by calculations for certain capacities) or were they simply adapted from Palladio's works of the 1500s? During the 1850s, much work was done in the theory of structures in various parts of the world so that during the last half of the 19th century, most truss design was based on fairly accurate analysis.[21] To state that Allan trusses were the first truly scientifically engineered timber truss bridges simply does not give sufficient credit to the earlier engineers. The scientific method of John A. McDonald is well documented both through his calculation book, which is currently held by Roads and Maritime, and also through his contributions to the Royal Society of NSW.[22] Although no record of Bennett's calculations remain, it is clear from his correspondence that his designs were based upon calculations of both the loads and the capacities. One such example is given in 1883:[23]

> *respecting an accident which happened at Telegra Bridge, and to your request that blinding of some description should be laid on the deck of the said bridge… the course proposed by you would shorten the duration of the bridges, and impose on the larger spans a weight they are not calculated to carry… William C. Bennett, Commissioner & Engineer for Roads.*

[19] DMR, *Timber Truss Bridge Maintenance Handbook*, Department of Main Roads NSW, February 1987.
[20] Source: Palladio, The Four Books of Architecture, 1570, book 3, p 17.; Roads and Maritime CARMS plans.
[21] Lynn Heather Mackay, *Timber Truss Bridges in New South Wales*, 1972 p 6.
[22] W.H. Warren, the strength and elasticity of ironbark as applied to works of construction, *Journal and Proceedings of the Royal Society of New South Wales*, v 20, 1886, pp 274-275.
[23] Official Correspondence, *The Maitland Mercury*, Saturday 16 June, 1883, p 4S.

Thirdly, were Old PWD timber truss bridges designed as stockier bridges made of very large cross-sections and long lengths of timber due to ignorance of other options, or another reason?

The 1865 report by Bennett does give hints as to the reason for not adopting the American style trusses, but the reason is definitely not ignorance of American technology, as has already been discussed. Following are excerpts from Bennett's report, with salient phrases underlined:

> *"…the simple queen truss with iron suspension rods, in spans of from 50 to 90 feet (15-27m), has been used, as giving the greatest headway and requiring least workmanship. When the headway has not been limited, a modification of this truss with radiating principals has been adopted, with the tie beam passing between the principals; it has been used in spans of from 60 to 100 feet (18-30m), and the laminated arch has been applied in spans of the same dimensions in some special cases where timber large enough for trusses could not be obtained. As yet, from want of full experience of the capabilities of the indigenous timber applied to intricate framing, and from the very shrinkage and warping which occurs if not seasoned, spans exceeding 100 feet (30m) have not been used…"* [24]

As noted in Section 2.1, at the time in which Old PWD type trusses were being designed and constructed, there was an almost unimaginable abundance of very large ironbark trees. As mentioned in Bennett's quotation above, he was trying to minimise costs by minimising the need for complicated or intricate workmanship which may have been beyond the skills of those available to construct bridges at the time. There was less workmanship required in the use of very large long timbers which were freely and abundantly available at that time. Bennett was also aware of the difficulties in using smaller sections of timbers because of the susceptibility of such timbers to shrinkage and warping. The use of very large and long timbers necessitated that timbers be cut from very old growth trees (approximately 200 years old), and these large cross-sections of the best quality timbers were less susceptible to shrinkage and warping than the smaller timbers from younger trees. Because these old growth trees are today no longer available, younger timbers have had to be used to replace deteriorated timbers in Old PWD trusses, and these timbers have not performed nearly as well as the original timbers in these bridges, thereby giving the Old PWD design a bad reputation which is unwarranted. Finally, Bennett designed with large timbers because he didn't have access to the level of information about the properties of the timbers as became available in 1886 when McDonald designed his truss. Bennett had to content himself with the information he had available to design strong, practical and economical bridges.

The 1998 MBK report claims that, "the technical benefits of the Old PWD truss were limited because there was little engineering science in their design and little practical input into cost-effective maintenance." [25] Tabulated below is a review of the "faults" alleged in the report.

[24] Roads (Report from Commissioner), *The Sydney Morning Herald*, Tuesday 12 December 1865, p 5.
[25] MBK, *Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW*, 1998, p 24.

Alleged Fault	Review in the light of current research
The segmental arch components of the truss [by which the report means the top chords and principals] were all made from single large-sized timbers which were hard to obtain and difficult to handle and install.	Although large sized timbers were becoming difficult to obtain by the early 1890s, at the time when Bennett was designing these trusses the timbers were plentiful, and the skill required in handling and installing the large timbers was less than the skill required for accurate cutting of large logs into smaller sizes while managing shrinkage and warping that occurred as the timber dried out.
It was extremely difficult to renew such members… because taking the defective member out immediately destroyed the structural integrity of the truss.	Although it is true that replacement of members in these bridges is exceedingly difficult, these bridges were only ever intended as low cost "temporary" bridges (approx. 30 years), put in place knowing that the opening of a new railway line or of a new area for settlement may radically change the required road alignment or transport needs, and that a "permanent" bridge could be constructed when funds became available, so this criticism is unfair.[26]
The vertical iron rods connecting the top and bottom horizontal timbers were comprised of single rods installed through the middles of these timbers… Had the theory of structures been applied, it would have shown that loads applied to the rods are larger near the ends of each truss. It is not surprising then that there were frequent breakages of the single rods which seriously weakened the truss span…	It is a fact that the outer vertical iron rods take a greater load. In most cases, larger diameter tension rods were provided at this location on Old PWD type trusses. However, it is not uncommon for engineers to specify a constant member size, especially for an inexperienced or unsupervised workforce. Had he specified smaller bars toward the centre, there was the risk they could have got mixed up on site with serious structural implications. There are therefore good practical reasons for a constant diameter to be adopted by Bennett. Moreover, it is unfair to criticise Bennett for the frequent breakages of the single rods as vehicle weights increased with amazing rapidity from one tonne in 1860 to six tonnes and a half by 1865 and then sixteen tonnes shortly after that.[27]
The bottom chords were made from four flitches or planks placed side by side on edge and cross bolted together… when the inner laminates deteriorated, it was extremely difficult to renew them…	Actually, Old PWD trusses have three lines of laminates, not four (McDonald Trusses have four). Again, this is an unfair criticism because Bennett had designed these bridges as temporary – the intention was to replace them after 30 years, not to renew members individually.
Shrinkage of the local hardwoods caused joints to open up such that the truss developed excessive sag…	Shrinkage and sag did not stop the original bridges from performing well beyond the expectations of the designer, with the average life being 54 years, and with 26 bridges remaining in service beyond 80 years.[28] The shrinkage and sag is much more of a problem today (using today's timbers) than it was with the original old growth timbers.

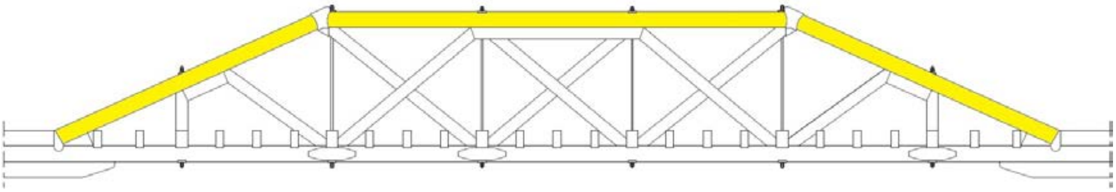
[26] Report of the Department of Public Works to the Legislative Assembly for the year ended June 1896, p 8; Percy Allan, "Timber Bridge Construction in New South Wales", 1895, p XII.
[27] "…as the roads are made passable are the loads on the drays increased. From one ton the load is increased to five tons on a pair of wheels, and to six and a half tons on four wheels…." *Sydney Morning Herald* 12 Dec. 1865, p 5.
[28] MBK, *Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW*, 1998, p 27.

2.2.2 Distinguishing features of the Old PWD design

The primary characteristics that distinguish William Christopher Bennett's designs for the Old PWD type timber truss bridges from other timber truss bridge types are examined in this Section (refer back to definitions in Section 1.6.2, including Figure 1-11 to Figure 1-13**.** for Old PWD truss terminology).

The top chords and end principals (see Figure 2-10) of an Old PWD truss consist of single large cross-section long sawn timbers, all of the same cross-sectional dimensions. The McDonald truss is the only other truss type with a single solid top chord, but the single solid principals are unique to the Old PWD truss. The later truss types (Allan, de Burgh and Dare) used not only paired members for the top chords, but also shorter lengths of timber with splices to make up the length.

Figure 2-10: Original 70' Old PWD design with top chords & principals highlighted.

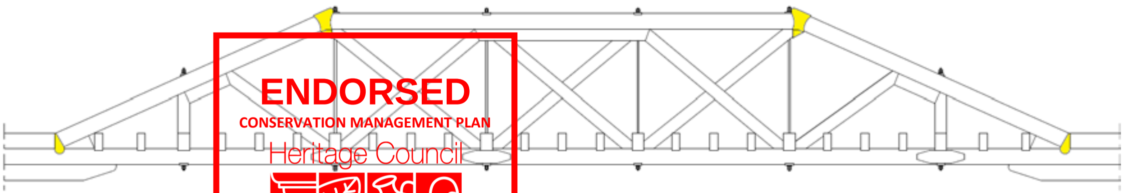


(source: author)

Principals in the Old PWD truss are significantly longer than diagonals (a feature shared with the McDonald truss), with a vertical timber prop approximately half way along the length and a vertical tension rod also at that location to support a primary cross girder. A timber spacer separates the vertical timber prop from the diagonal timber prop. Although the McDonald truss also has a diagonal prop, the vertical timber prop and spacer are unique to the Old PWD truss.

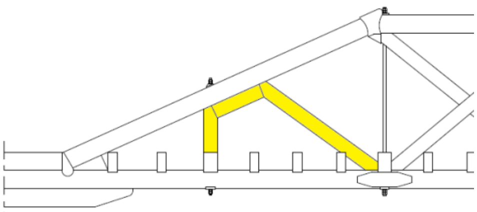
Principals are supported at the base on long timber butting blocks. Butting blocks are bolted to the bottom chord, and timber shear keys or notches are used to transfer the loads. There is a tear-drop shaped cast iron shoe provided between the principal and the butting block, which has always had this unique shape (see Figure 2-11). There is another cast iron shoe at the top of the principal connecting the principal, the top chord, a tension rod and some counterbracing. The shape and the details of this top shoe were modified quite substantially for different Old PWD truss designs. The use of shoes exclusively at ends of principals is unique to the Old PWD truss. McDonald had shoes only at the top chord (for both principals and diagonals) and none at the base of the principals, whereas the later truss types (Allan, de Burgh and Dare) had many more shoes.

Figure 2-11: Original 70' Old PWD design with cast iron shoes highlighted.



(source: author)

Figure 2-12: Props.



(source: author)

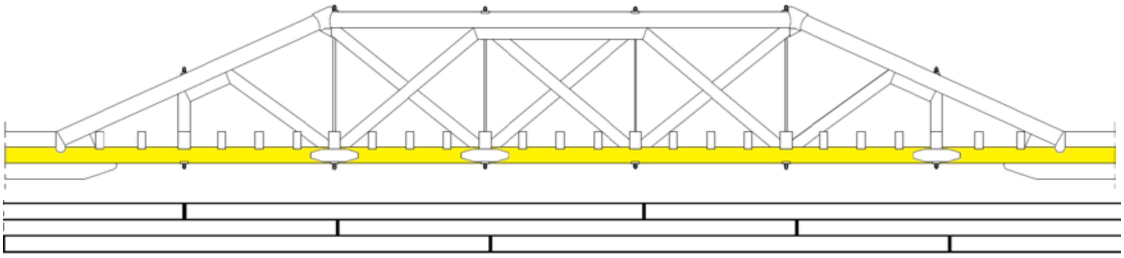
Timber sway braces are provided at all top chord panel points to laterally support the top chord and to resist sway of the trusses under vehicular loads. The use of timber sway braces is unique to the old PWD truss. Also unique to the Old PWD truss is the design of these members to provide lateral support to the top chord, whereas the later truss types (McDonald, Allan, de Burgh and Dare) provide other means to support the top chords.

Figure 2-13: Sway braces.

(source: author)

Bottom chords consist of three sawn timber laminates bolted together to form the same cross-section as the top chord and principals. Joints for all laminates occur only at panel points, and small metal fish plates are provided at each joint. The laminated timber bottom chords are continuous over piers and are common to the Old PWD and McDonald trusses, but the Old PWD always had three rows of laminates and the McDonald always had four (with long central metal splice plates at mid-span) because McDonald was designing for heavier loads. The fish plates in the bottom chord of the Old PWD were not designed to carry any load (as is clear from the fact that they exist even when the internal laminate is the only discontinuous laminate) which sets them apart from the McDonald and Allan designs. The fish plates were a clever innovation by Bennett to provide a bolting template to ensure the correct bolting arrangement was provided at all the joints.

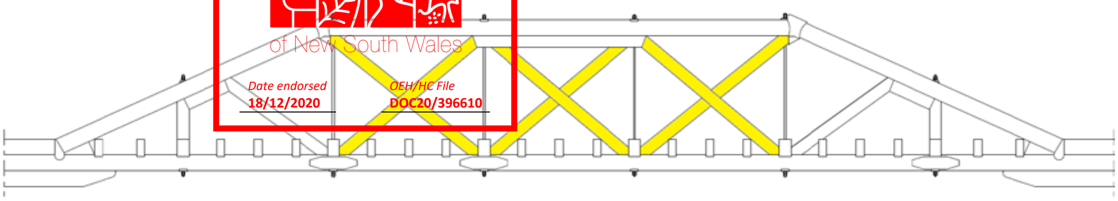
Figure 2-14: Original 70' Old PWD design with laminate layout of bottom chord.



(source: author)

Old PWD trusses had two, three or four counterbraced central panels, depending upon span length. Only two Old PWD trusses remain (70' and 100'), and both have three central panels.

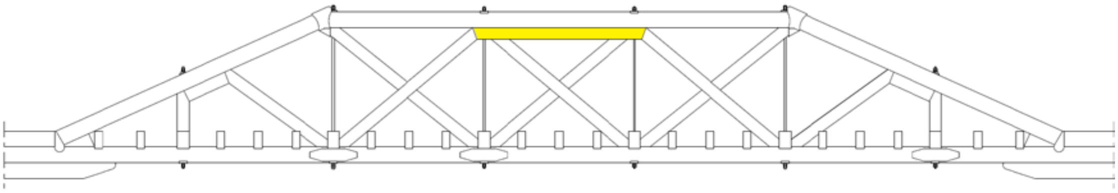
Figure 2-15: Original 70' Old PWD with counterbraced central panels highlighted.



(source: author)

For trusses with three central panels, the middle panel has a double top chord. Longer spans (e.g. Clarence Town) have the double top chord extending beyond the panel points, whereas others (e.g. Monkerai Bridge) have the double top chord stopping neatly at the panel points.

Figure 2-16: Original 70' Old PWD design with double top chord highlighted.



(source: author)

Single or double vertical wrought iron tension rods are installed through holes drilled in the top and bottom chords. Larger diameter tension rods are generally provided towards the ends of the top chords where stresses are higher than the smaller tension rods towards the centre of the span.

Cross girders in Old PWD trusses were generally (but not always) closely spaced, and generally (but not always) carried diagonal decking. These features are shared with the McDonald truss.

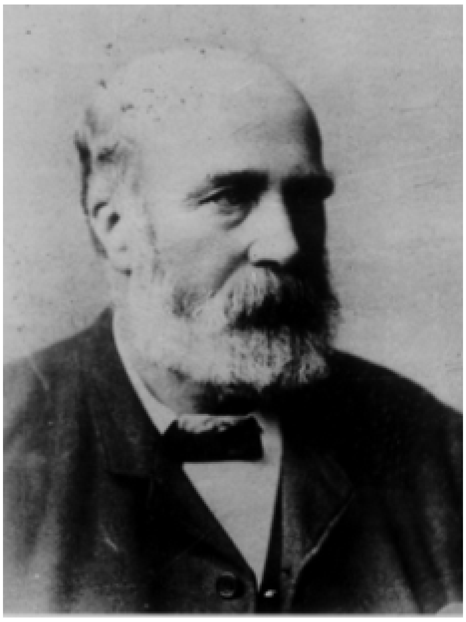
Railings consist of simple single (on smaller trusses such as Monkerai) or double (on larger trusses such as Clarence Town) rectangular timber rails, attached directly to the truss with no vertical posts. The Old PWD is unique in that there were no kerbs provided (which were provided on all other truss types), and there were no enlarged timber end posts (introduced in Allan truss bridges).

2.2.3 William Christopher Bennett (1824-1889)

William Christopher Bennett was born in Ireland on the 4th of July 1824. After being employed on territorial and railway surveys and drainage works in Ireland, by the age of twenty two he had four or five thousand men under him and was acting as District Engineer. He worked in Central America, England and New Zealand before coming to Australia at about the age of thirty.[29] Bennett was a man of courage, as can be seen from the following excerpt from his obituary:

> "Mr Bennett executed fully all the surveys and explorations entrusted to him, surveying and levelling by himself a large tract of country towards the Chucunaque River [Panama]; having no companion through that hostile country but black chainmen. He also assisted to bury some men belonging to H.M.S. "Virago" under the command of Captain Prevost, who were shot by the Indians while he was there; and afterwards accompanied Lieutenant

Figure 2-17: William Christopher Bennett



Source: MBK, Timber Truss Bridges 1998

[29] Obituary, "William Christopher Bennett", *Minutes of proceedings of The Institution of Civil Engineers*, 1890, pp 346-348.

Forsyth… for the rescue of Lieutenant Strain, of the US Navy, and his missing party, in which they succeeded; and for this service, Mr Bennett received the thanks of the American Government through the Secretary of the United States Navy…" [30]

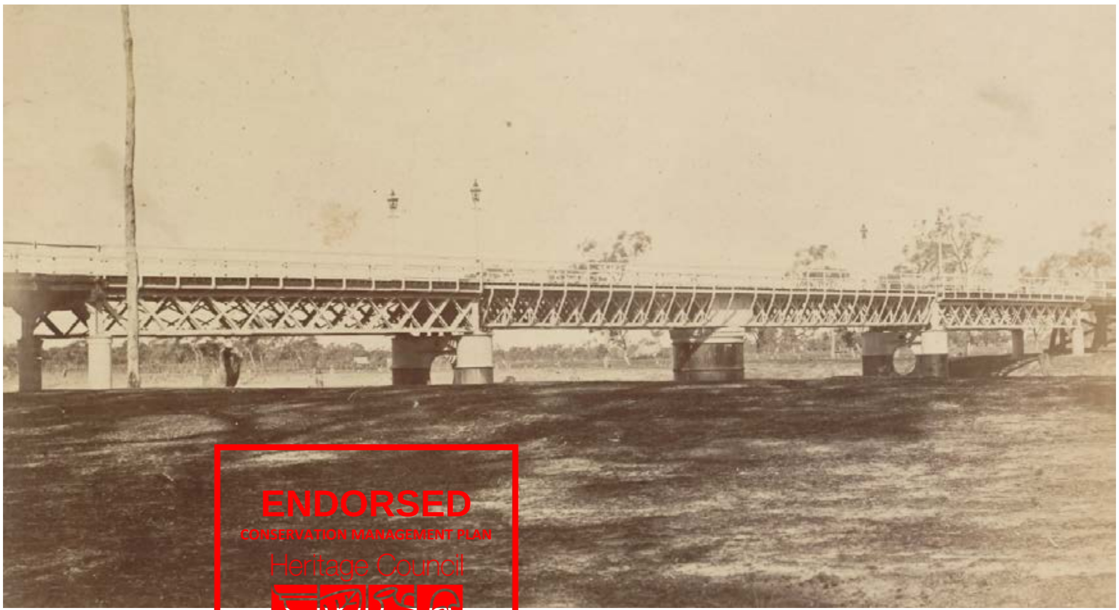
Bennett was appointed Assistant City Engineer in New South Wales in 1855 until 1856. He worked under John Whitton, the Engineer-in-Chief for Railways from 1857 until 1858 when he was selected by Captain Martindale, Commissioner for Internal Communication, to superintend the repair of a flood-damaged bridge at Bathurst. Martindale was so pleased with the manner in which this work was completed that he recommended Bennett for the position of Engineer to the Roads Department, to which he was appointed in January 1859 to January 1861. After an absence of twelve months, in which he returned to England, he worked again in the Railway Department under Whitton before receiving the appointment of Commissioner and Chief Engineer to the Roads Department, which he retained until his retirement on 1 July 1889.[31]

Bennett was well loved and respected by those who worked for him, as can be seen by the collection of letters written to him kept at the Mitchell Library.[32]

Up to the end of 1888, the total length of main roads built by Bennett and his department was nearly 16,000 km. About 40 miles (64 km) of bridges had been constructed, many of them the largest in the southern hemisphere, some remaining today.[33] A former colleague of Bennett wrote:

"*Our late chief, Mr W.C. Bennett… was a man of singular ability, prodigious energy, and untiring industry… The immense department which has grown up under Mr Bennett's control, and the work it has done, will probably not be chronicled till it, like he, has broken down under the strain, increasing as it does from year to year. Both have done their work nobly and well; both deserve the honour not always accorded where most merited.*" [34]

Figure 2-18: Hay Bridge, Murrumbidgee River ~ 1885, Bennett's photo album.



(source: Y3086F[35])

[30] Obituary, William Christopher Bennett, *Minutes of proceedings,* 1890, p 347.
[31] *Minutes of the proceedings of the Engineering Association of NSW*, vol. iv 1888/89, Memoirs pp 216-217.
[32] William Christopher Bennett - Records, 1850 - 1889, UMS 333; Mitchell Library Manuscripts Collection.
[33] Obituary, William Christopher Bennett, *Minutes of proceedings,* 1890, p 349.
[34] Obituary, William Christopher Bennett, *Minutes of proceedings,* 1890, p 350.
[35] Reproduced by kind permission of the Syndics of Cambridge University Library, NSW. Photos of Roads and Bridges. W.C. Bennett M. Inst. C.E., Commissioner and Engineer, Y3086F, photo #13.

Figure 2-19: Remains of Hay Bridge, Murrumbidgee River today.

(source: author March 2017)

The old Hay Swing Bridge was designed by Bennett (his signature is clearly displayed on the original design drawings, and a photograph is included in his photo album, as shown in Figure 2-18), and a large part of the castings and machinery for the bridge was made in Sydney at Messrs. P.N. Russell & Co.'s.[36] The bridge was completed in February 1873 under contract to the Department of Public Works and opened by Mr Henry Parkes on 29th August 1874.[37] Prior to the railway in 1882 the swing bridge at Hay opened for as many as six paddle steamers per day, whereas in the whole of 1883 only six steamers passed through.[38] When the bridge was replaced with a new concrete and steel bridge in 1973, almost 100 years later, the operating mechanism of the swing span was handed over to the Hay Historical Society and can still be viewed in a nearby park.

Figure 2-20: Prince Alfred Bridge Gundagai, Murrumbidgee River ~ 1885.

(source: Y3086F[39])

[36] *The Industrial Progress of NSW, being a Report of the Intercolonial Exhibition of 1870, at Sydney*, Sydney: Thomas Richards, Government Printer, 1871, p 475.

[37] DMR, *Main Roads*, Vol 39 #1, Journal of the Department of Main Roads, NSW, September 1973, p 3.

[38] G. L. Buxton, *The Riverina 1861-1891: An Australian Regional Study*, Melbourne University Press, Melbourne, 1967, p 217 cited in GHD, Movable Span Bridge Study, Volume 1, March 2015, p 31.

[39] Reproduced by kind permission, Cambridge University Library. W.C. Bennett, Y3086F, photo #19.

Figure 2-21: Prince Alfred Bridge Gundagai, Murrumbidgee River today.

(source: author 2012)

The Prince Alfred Bridge at Gundagai was the first metal truss bridge to be built in New South Wales. Designed by Bennett and opened in 1867, it is the second-oldest metal truss bridge remaining in Australia, and carried Hume Highway traffic until it was bypassed in 1977. Since that time it has carried local traffic from South Gundagai to Gundagai. According to Bennett, the Warren girder had been adopted, because it required the least workmanship on the ground, and because of the rapidity with which it could be erected, incurring least risk from the violent floods of the Murrumbidgee during construction.[40] The cast iron piers are unique because they were cast in at the Fitzroy Iron Works, the first ironworks in Australia, chiefly from local ores.[41] By 1932 there were thoughts to replace the bridge, but it was admitted that, "the existing iron trusses, though light and of unusual design, viewed from the aspect of modern structural practice, were in good order and were capable of rendering efficient service for the life of at least one more timber approach." [42]

Figure 2-22: Denison Bridge Bathurst, Macquarie River ~ 1885, by Bennett.

(source: Y3086F[43])

[40] Lynn Heather Mackay, *Iron Bridges in NSW*, An Essay, University of Sydney, 1972, p 23.
[41] Colin O'Connor, *Spanning Two Centuries, Historic Bridges of Australia*, Queensland: University of Queensland Press 1985, p 30.
[42] DMR, *Main Roads*, February 1932, Vol III #6, Journal of the Department of Main Roads, NSW, p 89.
[43] Reproduced by kind permission, Cambridge University Library. W.C. Bennett, Y3086F, photo #30.

Figure 2-23: Denison Bridge Bathurst, Macquarie River today.

(source: author 2013)

Opened in 1870, Denison Bridge over the Macquarie River in Bathurst is the second-oldest metal truss bridge in New South Wales, and carried Great Western Highway traffic until it was bypassed in 1992. Since that time it has continued as a pedestrian crossing. The drawings and detailed calculations for the bridge were made by Gustavus Alphonse Morell, assistant engineer to Bennett, and his signature (along with Bennett's) appears on the original design drawings.[44] The iron bars were supplied by the Fitzroy Iron Works at Mittagong, structural shapes were formed from it at the Pyrmont Rolling Mills and the fabrication / erection was carried out by the Sydney company P.N. Russell & Co.[45] The Denison Bridge is detailed in such a way that it could be mistaken for a more modern bridge, being a Pratt type truss, with the web of the upper chords placed horizontally so as to achieve a high transverse bending strength and a good resistance to buckling.[46]

Figure 2-24: Urara Bridge, Newton Boyd Road ~ 1885, by Bennett.

(source: Y3086F[47])

[44] Engineering Heritage Committee, Sydney Division, Engineers Australia, *Nomination of the 1870 Denison Bridge Bathurst as an historic engineering marker*, November 1994, pp 14-15.
[45] Lynn Heather Mackay, *Iron Bridges in NSW*, An Essay, University of Sydney, 1972, p 25.
[46] Colin O'Connor, *Spanning Two Centuries, Historic Bridges of Australia*, 1985, p 31.
[47] Reproduced by kind permission, Cambridge University Library. W.C. Bennett, Y3086F, photo #59.

Figure 2-25: Bawden Bridge over the Orara River today.

(source: author 2013)

Bawden Bridge crosses the Orara River approximately 16 km south-west of Grafton. Opened in 1874, it was also designed by Bennett, and is particularly notable for its high, heavy metal piers.[48] The iron work was constructed at Mort's Foundry, Sydney, and the bridge remains in use today.[49] Although Bennett designed a vast number of very different bridges, he felt that wrought iron lattice truss bridges were superior where workmen and material could be obtained without much difficulty and where the flood risk was not as great as at Gundagai, and so this is what he designed here.[50]

These four metal bridges demonstrate something of Bennett's ability as a bridge designer, making use of many different materials and configurations as best suited to the needs of a particular site.

In addition to his prodigious work on roads and bridges in New South Wales, Bennett also made a significant contribution to navigation, water supply and sewerage works. In 1852 he accepted appointment with Gisborne & Forde to go from Ireland to South America and report on the navigation of the Magdalena River, its connection with the sea by canal and the possibilities of a further canal link with Bogota, capital of Nueva Granada (Colombia). As a preliminary he toured the Rhone and Saône Rivers in France to study methods of river navigation by large boats. After he returned to England from Colombia, he helped to plan a proposed embankment for the Thames, which was, however, never implemented. In 1853 he re-joined Gisborne & Forde in another expedition to Latin America, this time in charge of surveying and exploring the Pacific side of the Isthmus of Darien for the international ship canal. It was there that he also assisted Lieutenant Forsythe and a detail from H.M.S. Virago in the hazardous rescue of a missing exploration party of United States navy personnel under Lieutenant Strain.[51] Interestingly, this expedition was written up, illustrated and appeared over three successive editions of the 1855 *Harper's New Monthly*, a periodical of the day, with glowing reports of Bennett's contributions.

[48] Colin O'Connor, *Spanning Two Centuries, Historic Bridges of Australia*, 1985, p 32.
[49] DMR, *Main Roads*, March 1954, Vol XIX #3, Journal of the Department of Main Roads, NSW, p 74.
[50] W.C. Bennett, "Roads (Report from Commissioner) Report on the state of the Roads in the colony of New South Wales, to 31 March 1865, Department of Public Works, Roads Branch, Sydney, 31st March 1865", *The Sydney Morning Herald*, Tuesday 12 December 1865, p 5.
[51] Robert Johnson, 'Bennett, William Christopher (1824–1889)', *Australian Dictionary of Biography*, National Centre of Biography, Australian National University, http://adb.anu.edu.au/biography/bennett-william-christopher-2976/text4339, published first in hardcopy 1969, accessed online 26 April 2017.

"*The noble-hearted Bennett… a stranger and foreigner - this grand, high purpose to cast his lot in with the distressed commander, and save his party, or perish with them - reveals one of those lofty, elevated characters which shed lustre on the race.*" [52]

After moving to Australia, Bennett was, for a time, assistant city engineer on sewage works under Edward Bell. In 1857 Bennett and a subordinate, W. B. Wade, won a competition for designing the Launceston sewerage system. In the field of water supply and sewerage in Sydney Bennett was appointed to special commissions in 1868, 1875 and 1888, and two standing boards as an additional member. He also served in commissions on Sydney's water supply in 1868, on Hunter River floods in 1869 and on Darling Harbour in 1878, and gave evidence to several select committees on various engineering problems.[53]

Letters and testimonials from his superiors, subordinates and friends indicate that Bennett had great ability both as an engineer and as an administrator. In his own words, he was "naturally, and by habit, anxious and energetic".[54] In particular he was anxious for assurance of the approval of his superiors, and apt to offer resignation if he lacked it. Yet he distrusted public approbation and avoided limelight. Ambitious in the tasks he was prepared to undertake, he drove his subordinates hard but was loyal and generous in return and made staunch friends among them. In 1872 Sir Henry Parkes, speaking in support of an increase in Bennett's salary to £1000, described him in parliament as, "one of the ablest officers in the government service" and asserted that he had been grossly underpaid for his important and competent work.[55] Bennett was diligent to the end:

> *About the month of March he had an illness, caused by failure of action of the heart, when his medical adviser urged him to give up the heavy duties he was performing; but being desirous of seeing the completion of some important works then in hand, he continued on until the month of June, at which date he became so seriously ill that he sent in his resignation, and retired on his well-earned and ample pension, while the Government, in recognition of his able services in carrying out the city and suburban sewerage works, submitted to Parliament a vote on the Supplementary Estimates for 1888 of £2,700, as a gratuity for the supervision of this gigantic work, which was readily granted. Unfortunately, he did not long survive these advantages, and from the date of his retirement was scarcely able to leave his bed. His death took place on the 29th of September, 1889.* [56]

2.3 History of the area around Monkerai Bridge [57]

2.3.1 Early European settlement of the Hunter Region

The study area falls into the "Gringai" tribal area of the Wonnarua people identified by Tindale in 1974. "Dungog" or "Tunkok" is reputedly a local Aboriginal name meaning "place of thinly wooded hills" or "clear hills", while Karuah is the term for the native plum tree.[58]

The European discovery of what became known as the Hunter River was by Lieutenant John Shortland Junior in 1797, prior to this in 1796, coal pieces obtained by fishermen sheltering in

[52] J.T. Headley, Darien Exploring Expedition, *Harper's New Monthly Magazine*, Mar, Apr, May 1855, p 759.
[53] Robert Johnson, *Australian Dictionary of Biography*.
[54] Robert Johnson, *Australian Dictionary of Biography*.
[55] Robert Johnson, *Australian Dictionary of Biography*.
[56] Obituary, William Christopher Bennett, *Minutes of proceedings,* 1890, p 349.
[57] This section (2.1) is copied directly from: Dr Sue Rosen and Dr Sid French, Conservation Management Plan, Monkerai Bridge, Prepared for Roads and Maritime Services, December 2016 DRAFT, pp 12-17.
[58] Frederick D McCarthy, The Australian Museum, New South Wales *Aboriginal Place Names and Euphonious Words, with their Meanings*, A.H. Pettifer, Government printer, Sydney, 1952, pp. 12; 14.

the estuary of the river had inspired European interest in the area and by 1799 traders had shipped a cargo of coal to Bengal.[59] Thus began the European occupation of the Hunter Valley.

In July 1801 Governor King declared:

> *… the coals and timber which are to be procured at Hunter's River to be the exclusive property of the Crown and having thought fit to establish a port at Freshwater Bay ... he strictly forbids any boat or vessel going there ... without obtaining a special license.*[60]

In March 1802 a settlement was established at the mouth of the river by five rank and file members of the New South Wales Corps, this first settlement was abandoned in June due to the 'improper conduct' of the person in charge, and it was not until 1804 that a second attempt at settlement was made under the Command of Lieutenant Menzies. A surgeon, eleven non-commissioned officers and privates of the New South Wales Corps, a superintendent, an overseer and between 34 and 50 of the 'worst' Irish convicts, who had been involved in the Castle Hill uprising, established the first permanent settlement on Hunter's River which was to become known as Newcastle.[61]

Supplies of coal and cedar were to be obtained from the area under license and the supervision of Commandant Menzies with the settlement serving as a secondary transportation site for convicts who had been found guilty of offences in New South Wales. Prisoners were to mine coal under the direction of professional miners and were to get cedar from the upper parts of the river to Newcastle for Government and private use. By August reports of the extent and fertility of the land in the Hunter Valley had influenced King to consider settling the area with people recently removed from Norfolk Island.[62] Settlement by free settlers, however, did not occur until after the closure of the penal establishment at Newcastle in the early 1820s.

The cedar getters were responsible for the initial opening up of the area. In 1805, soon after settlement, Commandant Menzies returned from an exploratory cedar getting expedition with '70 logs on a raft containing upwards of 26 000 feet of Timber', and reported on a site located some 40 miles upriver which would make a 'capital Government Farm'.[63] As the penal settlement grew large tracts of land were cleared and knowledge of the interior expanded. By September 1813 there were 242 'souls' in the Newcastle settlement including 12 victualled free persons, 159 victualled prisoners and 18 people not victualled.[64] Land on the Maitland Flats was under cultivation.[65]

By 1819 the fertile land and its accessibility via the river caused the area to:

> *become an Object of Valuable Consideration in the Necessary Increase of the Population, and hold out important advantages for the Establishment of Free Settlers upon them.*[66]

It was noted by Governor Macquarie that:

> *Newcastle now Ceases to be of that Material Benefit, which it was formerly ... as a Receptacle for our worst Characters, in Consequence of the Interior having been Explored, and the Passage thence to Windsor on the River Hawkesbury having become*

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[59] J.F. Campbell, 'The Genesis of Rural settlement on the Hunter', *The Journal of the Royal Australian Historical Society*, Vol. XII, 1926, Pt. 2, p. 73; *Historical Records of Australia*, Vol. II, p.713; *The Australian Encyclopaedia*, Vol. V., p.35.
[60] Governor King, *Historical Records of Australia*, Series I, Vol. III, p.257.
[61] Governor King, *Historical Records of Australia*, Series I, Vol. IV, pp.420; 528; 612 and 694.
[62] Governor King, *Historical Records of Australia*, Series I, Vol. V, p. 6; 82; 486; 623.
[63] Governor King, *Historical Records of Australia*, Series I, Vol. V, p. 416.
[64] Governor Macquarie, *Historical Records of Australia*, Series I, Vol. VIII, p. 18
[65] T.M. Burley, "The Evolution of the Agricultural Pattern in the Hunter Valley of New South Wales", *Australian Geographer*, Vol.8, No.5, Sept., 1962, p.223.
[66] Governor Macquarie, *Historical Records of Australia*, Series I, Vol. X, p. 43.

familiar to several of those Persons who have been transported thither, and who now find little Difficulty in deserting.[67]

In 1820 John Howe spent five weeks exploring the valley of the upper Hunter River and was rewarded by Macquarie with a license to graze his stock on ‘St. Patrick's Plains’ (Singleton) which he had discovered. Howe was later granted 700 acres in the area.[68]

In 1821 approval was received from Lord Bathurst, Secretary of State for the Colonies, to establish a penal settlement at Port Macquarie and to close the Newcastle establishment. By this time the Hunter Valley cedar stands had been depleted and reservation of the area for timber getting ceased. Considered ‘waste lands of the Crown’ the land was available for settlement, with the problem facing Governors of how to supervise and control the expansion of settlement. In 1825 instructions were received by Governor Brisbane for the division of the colony into counties and parishes. Land was to be surveyed and valued prior to settlement which Lord Bathurst envisaged would follow the ordered British system.[69]

By 1830, the Hunter Valley had more European occupiers and more land under cultivation than any other frontier district. Occupation was by boat via the Hunter and its tributaries, some 1.5 million acres had passed into private hands by 1830 with most river frontages occupied.

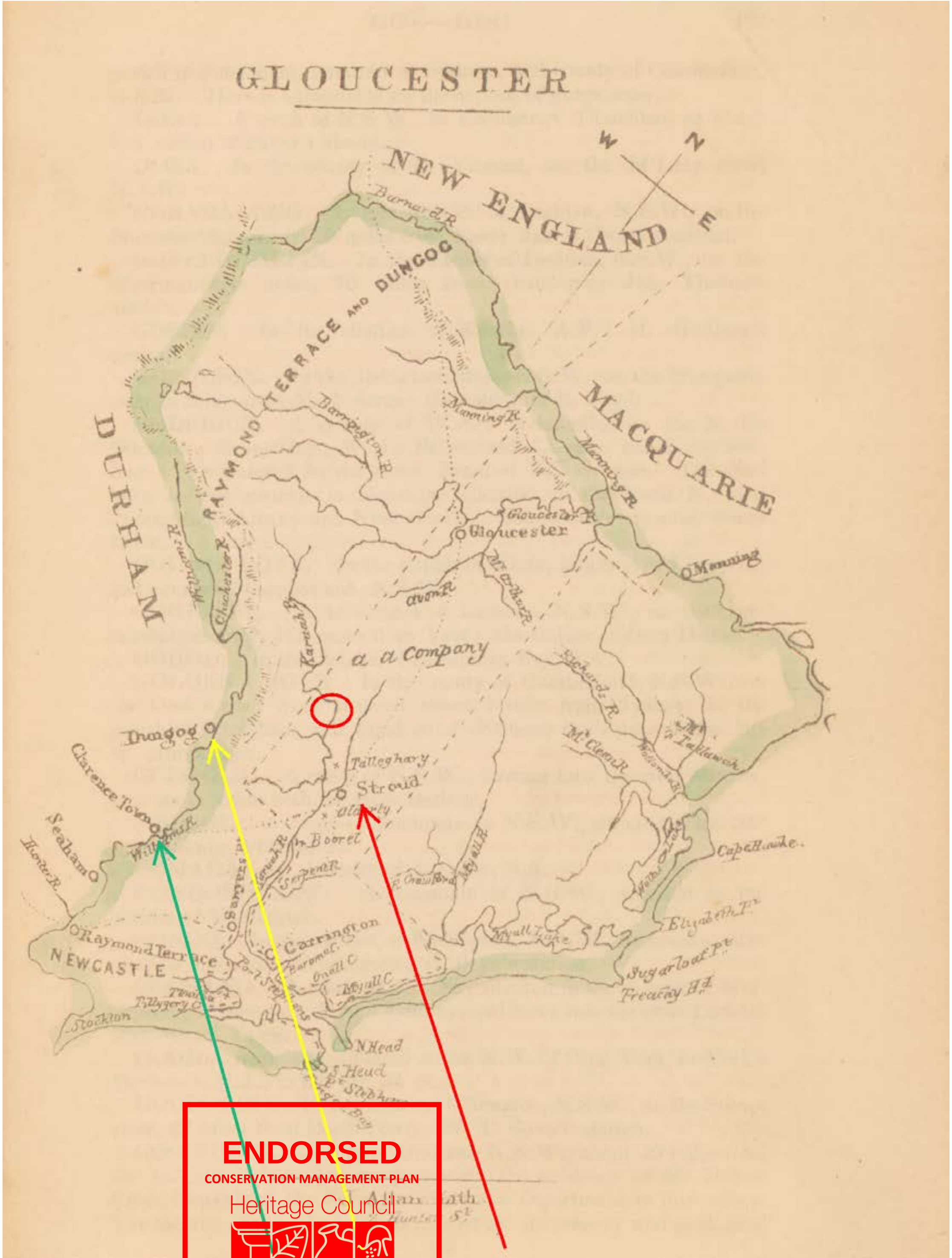
2.3.2 General development of the Dungog and Stroud areas

The early history of the Dungog and Stroud area is linked to the formation of the Australian Agricultural Company (AAC) in London in 1824. The AAC was formed to raise funds to exploit the grazing possibilities of NSW. A nominal one million pound’s capital was raised which entitled the Company to a Crown Land Grant of one million acres. The directors sat in London, but there was a colonial board in Sydney. The site, stretching from the northern side of Port Stephens to the Manning River was selected in early 1826 by Manager, Robert Dawson, on the recommendation of Surveyor General John Oxley. It became known as the Port Stephens Estate, and the company’s local headquarters were moved to Port Stephens by the end of the year. In 1829 one hundred and fifty convicts and 89 servants from the UK planted crops and set up sheep runs along the Karuah River. However, the farming practices of the AAC quickly depleted the land and in 1830 they sought to relinquish half the estate; in 1831 the company obtained a new grant on the Liverpool Plains. They retained the balance, known as the Gloucester Estate, until 1903 when it was sold. The town of Stroud owes its origins to the company.[70]

[67] Governor Macquarie, *Historical Records of Australia*, Series I, Vol. X, p. 43.
[68] Governor Macquarie, *Historical Records of Australia*, Series I, Vol. X, pp. 178; 811.
[69] J.F. Campbell, ‘The Genesis of Rural settlement on the Hunter’, 1926, Pt. 2, p. 74.
[70] C.J. King, *An outline of Closer Settlement in New South Wales*, Department of Agriculture NSW, 1957, pp.33-38; Chapman (ed.), 1997:568 cited in RTA Operations Environmental Technology Branch, SOHI Proposed rehabilitation and strengthening works on Monkerai Bridge over the Karuah River, Dec 2004, p.2.

Figure 2-26: The approximate location of the Monkerai Bridge is encircled in red on this 1848 map of the county of Gloucester.

– the red arrow points to Stroud; the yellow to Dungog and the green to Clarence Town. The broken line borders the Australian Agricultural Company grant[71]



2.3.3 Monkerai

Monkerai is a rural locality situated between Dungog and Gloucester, which is traditionally timber and dairying country surrounded by state forests and national parks. Monkerai Bridge is located on land originally granted to the Australian Agricultural Company which sold off in

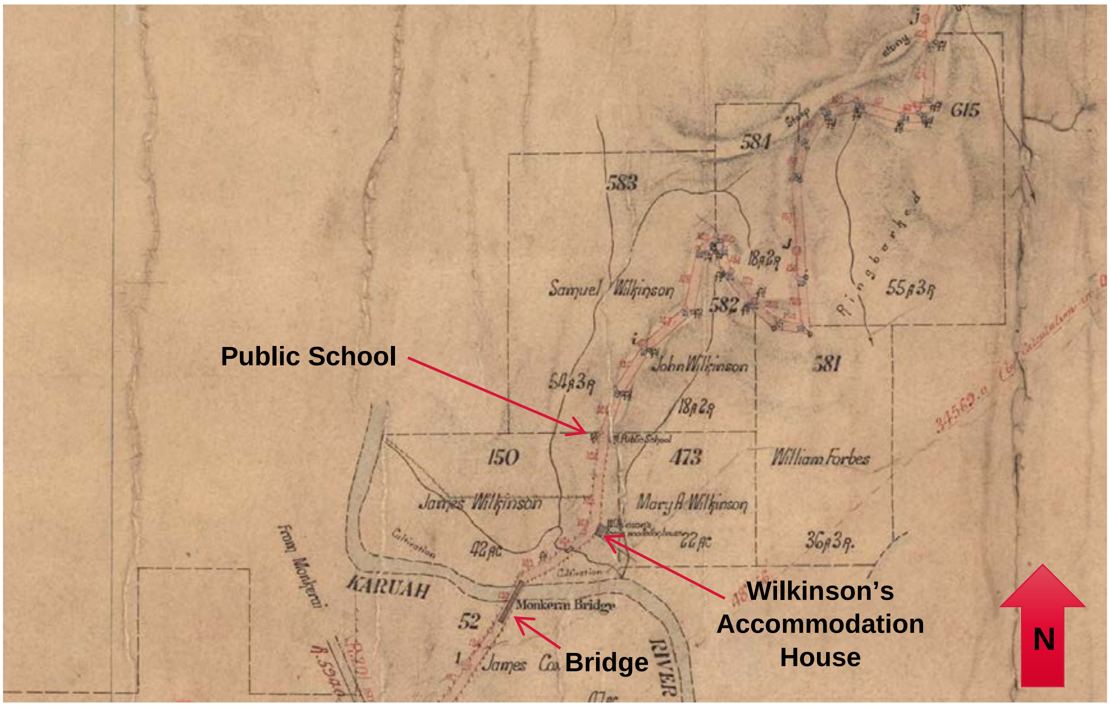
[71] William Henry Wells, F & W Ford, 1848. NLA MAP RaA 14.

1903 and subject to re-subdivision as part of the Weblands Park Estate in the 1960s.[72] The bridge is sited on the South on the former Portion 52, Parish of Monkerai and on the North by former Portion 150, to the immediate West of the Agricultural Company's holdings.[73]

During the later 19th century the road through the picturesque Monkerai Valley provided the main road link between the villages of Dungog and Gloucester. The best route to the Barrington diggings of the 1870s was via Monkerai. The trees for the road were marked for horsemen and the construction undertaken by a 'few Dungog residents'.[74] The establishment of Wilkinson's Accommodation House near the bridge/ford is likely to be associated with the establishment of the route (Figure 2-27). The need for a bridge spanning the Karuah River at Monkerai, to eliminate the existing ford and the associated delays experienced during times of flood, was finally met when, in 1882, the existing timber truss bridge was opened.

Figure 2-27: This extract from the survey of the Stroud

– Gloucester road shows that in 1893, Samuel, John, James and Mary Wilkinson occupied [sic, owned] portions 583, 584, 582, 473 and 150 on the northern side of the bridge and that the areas along the Karuah River on either side of the bridge were under cultivation. "Wilkinson's Accommodation House" is shown beside the road on Portion 150,[75] with the School located near the boundary with portion 482 [sic, 582]. To the south, portion 52 was occupied [sic, owned] by James Cox. [LPI: Plan R5029-1603]



(source: figure is taken from draft CMP 2016, annotations in green are by the author).

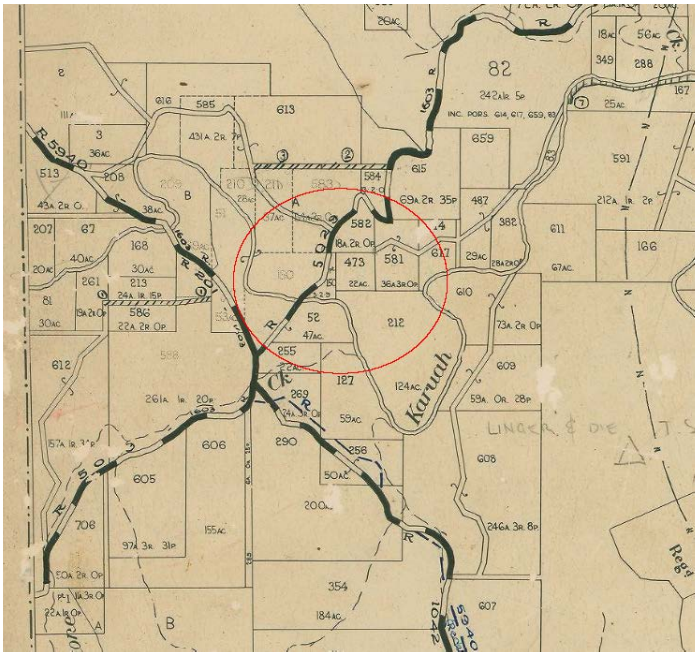
Speedier and more regular communication between the Hunter River and Manning districts had been a matter of concern from at least June 1877. In a letter to the editor of the Maitland Mercury and Hunter River General Advertiser an improved line of road to that via Maitland and Stroud was advocated. The new line from Maitland would proceed to Dungog and on via Monkerai. The proponent commented that although the road around Monkerai Hill was in a bad state, 'almost in a state of nature', it could be readily made a first class road with little expenditure. The Barrington goldfields by then had a population of upwards of 70 miners and quartz crushing machines were being erected. At the time Monkerai was a 'small agricultural

[72] LPI: DP 216749.
[73] LPI: Plan R5029-1603
[74] *Maitland Mercury and Hunter River General Advertiser*, 22 October 1878, p 5 cited in Michael Williams, A History in Three Rivers: Dungog Shire Heritage Study Thematic History, August 2014, p.80.
[75] The boundary of 150 and 473 are obscured by a crease in the plan.

settlement' supplied by pack horse as the 'road' was impassable for drays, however the area showed much promise for closer settlement.[76] In further correspondence to the Mercury it was argued that the Monkerai route was impossibly expensive because of the necessity to cross the Karuah three times – at Wilkinson's, again between Wilkinson's and Langworthy's and at Langworthy's, and that "Each of these crossings would require bridges, and each bridge, especially the first and the last, would, with approaches, cost at least £2000." At Monkerai the Karuah was 'dangerous, broad and rapid'. Advocates of the Monkerai route were thought to be attempting to divert traffic to Dungog, away from Stroud for their own commercial gain.[77]

Two thousand pounds had been made available for a new road, and the route via Clarence Town and Dungog was purported to be 6 miles shorter than via Stroud and 11 miles shorter than by Stroud and Raymond Terrace. Provision had been made in the estimates for £8000 for a bridge over the Williams River at Clarence Town. Monkerai Hill had long been considered a barrier to progress for the Monkerai locality, confined as it was to local traffic by Monkerai Hill which diverted other traffic to the north.[78]

Figure 2-28: The extract from the April 1962 Parish of Monkerai Map, shows portions in the vicinity of the bridge prior to subdivision in the 1960s [Six Maps]



In July 1877, three surveyors were in the Monkerai area subdividing for government, church and school lands. In a proposed new coach timetable from West Maitland to Tinnone, the 14 miles from Dungog to Weismantle's was scheduled between 2.15 pm to 5:30 pm. The portion over Monkerai Hill was 2 miles from base to base, very steep and rough, but a new line about a mile to the north-west there was a gap where a new road with an easy gradient was suggested. The five miles from the eastern base of Monkerai Hill to Wilkinson's was a good and level road, and although not the main road, was used by loaded drays and buggies in flood, avoiding two crossings of the Monkerai [sic, Karuah] River.[79]

In February 1881 it was announce by the Commissioner for Main Roads that tenders had been called for construction of the bridge over the Karuah River at Wilkinson's. Progress on the 'Monkerai Deviation' on the road from Dungog to Stroud was well in hand, 1.5 miles of cutting of the 'big hill' was in progress and drawings were in preparation for the bridge at Wilkinson's and it was expected that the deviation would be trafficable in two months.[80]

[76] *Maitland Mercury and Hunter River General Advertiser*, 9 June 1877, p.7.
[77] *Maitland Mercury and Hunter River General Advertiser*, 21 June 1877, p.7.
[78] *Maitland Mercury and Hunter River General Advertiser*, 26 June 1877, p.7.
[79] *Maitland Mercury and Hunter River General Advertiser*, 14 July 1877, p.10.
[80] *Maitland Mercury and Hunter River General Advertiser*, 15 February 1881, p.7.

2.4 Design and construction of the bridge

2.4.1 The need for the bridge

While the need for the bridge at Monkerai was largely covered in the previous section, there the emphasis was on the importance of the route for the region, rather than for the locals of Monkerai. The following newspaper articles graphically illustrate the need of the locals for a reliable bridge.

> *FATAL ACCIDENT. – The long-continued rains have kept the rivers fresh. It appears some of the children at the Monkerai crossed to school on horseback, on Wednesday afternoon. Two of Mr. Relton's children, a boy and girl, returning from school, and, as far as I can learn, both mounted on one horse; in crossing the horse was carried off his feet, and both children thrown into the river. The girl scrambled out, but the poor boy (seven or eight years old) was drowned… The river at the Monkerai ought to have been bridged long ago…*[81]

Monkerai… The attendance at our Public school has been very low, through the river having been flooded so frequently; indeed, for about twenty times since the beginning of the year. Parents have placed logs across the river in order that their children might get over, but no sooner have these logs been placed in their position than ominous clouds have obscured the horizon, heavy rains have fallen, the river has risen, and the logs been swept away… I think we ought to make a move towards getting a good bridge over the Karuah.[82]

2.4.2 The construction of the bridge

There is very little information available on the original construction of the bridge. The earliest Roads and Maritime file entry for Monkerai Bridge is a file note in the bridge general file from 1922 which, among other things, incorrectly states that the bridge was constructed in 1877 at a cost of £3,500.[83] Monkerai Bridge is one of the few remaining timber truss bridges for which very little appears to have been written in the local newspapers of the day regarding its construction or its opening. In fact, there is no record of an official opening or a date for the completion of the bridge.

William Christopher Bennett reported on 21 January 1881 that drawings were being prepared, "for bridge over Karuah at Wilkinson's".[84] Tenders were called for the construction of the bridge in the Government Gazette of 25 February 1881, and the contract was awarded to M. Murphy in the Government Gazette of 26 April 1881.[85] The bridge was reported complete by March 1882:

> *Mr David Bailey of Bullock Island, subcontractor under Mr Murphy, has just completed a capital bridge across the river Conra* [sic, Karuah]*, on the road between Stroud and Dungog. The cost was about £2000 and the time occupied some seven months. The bridge is some 320 feet long, consists of three trusses, and is constructed of best hardwood throughout. The workmanship, we are informed by several eyewitnesses, reflects much credit upon those who carried the contract out, and the bridge itself will prove of no small convenience to the travelling public of that locality.*[86]

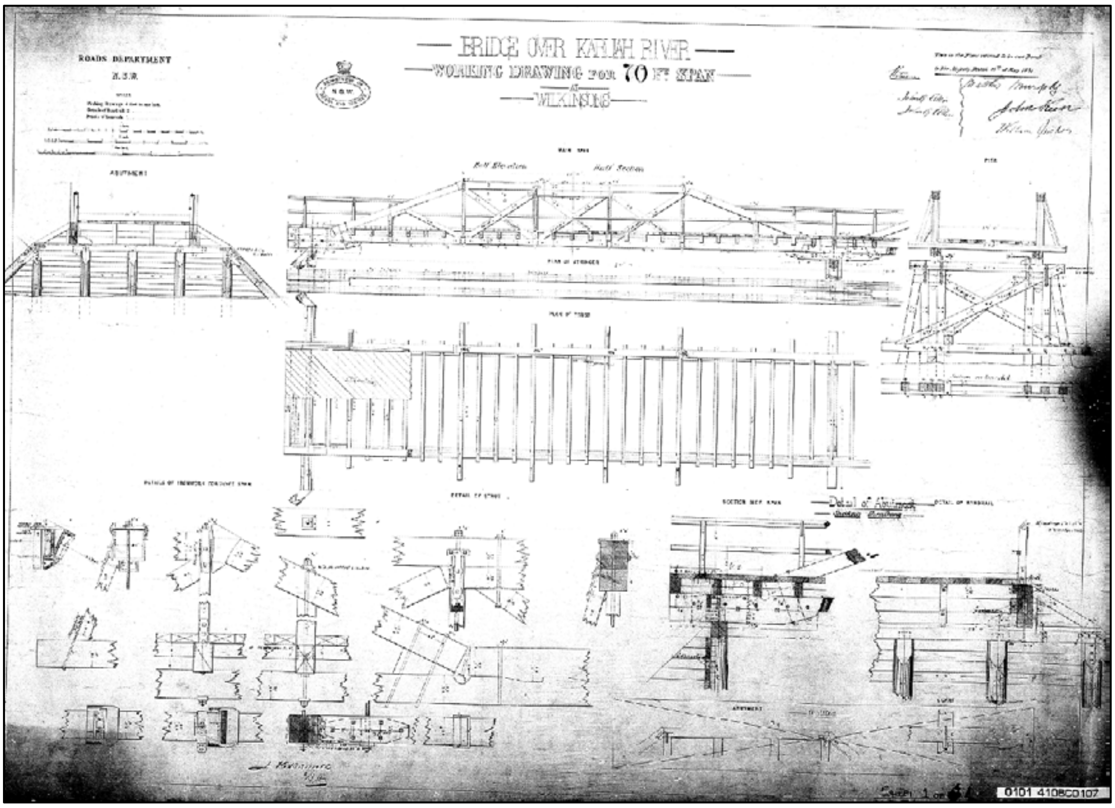
There are four design drawings for the bridge over Karuah River at Wilkinson's which were signed in 1881, but none of these reflect exactly what appears to have been constructed, and even these four drawings show at least four different options for approach span configurations.

[81] *Maitland Mercury and Hunter River General Advertiser*, Tuesday 27 April 1873, p 3.
[82] *Maitland Mercury and Hunter River General Advertiser*, Tuesday 13 July 1875, p 3.
[83] SRNSW: File 410.62 – 1 at 14/13302 cited in Sue Rosen Associates draft CMP, 2016, p 24.
[84] *Maitland Mercury and Hunter River General Advertiser*, Tuesday 15 February 1881, p 7.
[85] Don Fraser, Timber Truss Bridges NSW Database, unpublished, 1998.
[86] *Newcastle Morning Herald and Miner's Advocate*, Saturday 11 March 1882, p 5.

Only relatively poor quality and difficult to read scanned copies have been retained by Roads and Maritime.[87] The earliest photograph available of Monkerai Bridge (undated, approximately 1930s) is shown in Figure Figure 2-35.

The first drawing (Figure 2-29) shows the standard details for the 70' (21.336 m) Old PWD type truss span as well some drawings of standard abutments and piers, but without sufficient details to construct the piers and abutments. Some of the dimensions on the truss span drawings are illegible, but because it is a standard working drawing, similar drawings for other bridges can be viewed in order to obtain the dimensions or details which are not clear on this drawing. This means that all the original design details of the truss spans can be known with some certainty.

Figure 2-29: Original Drawing for Truss Spans at Monkerai Bridge.

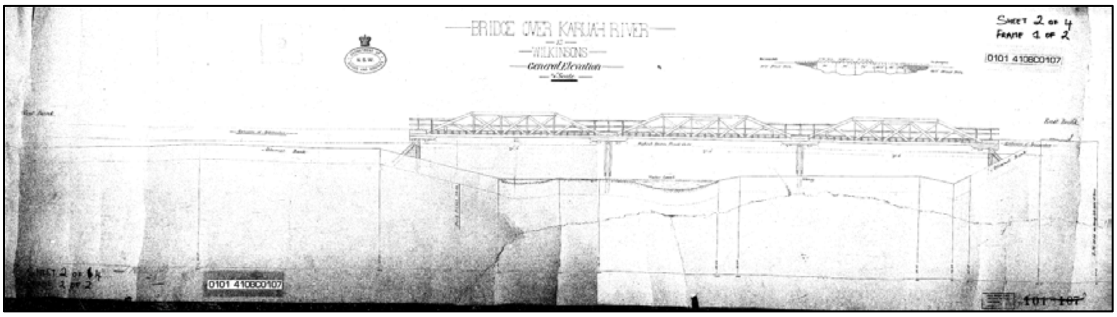


(source: 0101 410 BC 0107 #1)

The second drawing (Figure 2-30) shows a general arrangement, but the general arrangement is for a relatively low level bridge with only three spans, all truss spans, and no approach spans. There is a little diagram in the top right hand corner (enlarged in Figure 2-31) which shows a higher level bridge with three truss spans and three approach spans, but it is not clear when this diagram was added. It is probably not part of the original 1881 drawings because the span lengths in the diagram do not match the span lengths provided on the third drawing. It is possible that the diagram shows the works as executed, but it is more likely that it was added at a later date.

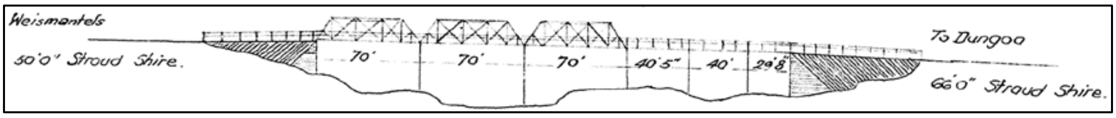
[87] Drawing Registration Number 0101 410 BC 0107.

Figure 2-30: General Arrangement Drawing for Monkerai Bridge.



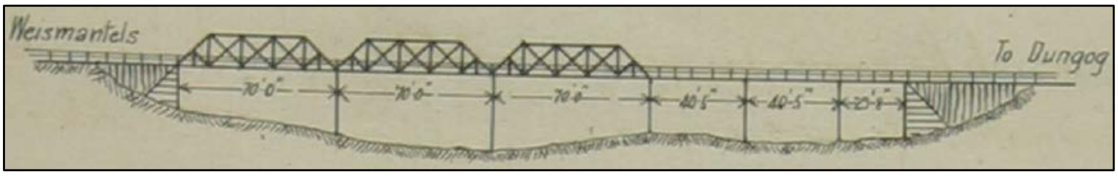
(source: 0101 410 BC 0107 #2)

Figure 2-31: Excerpt from General Arrangement Drawing.



(source: 0101 410 BC 0107)

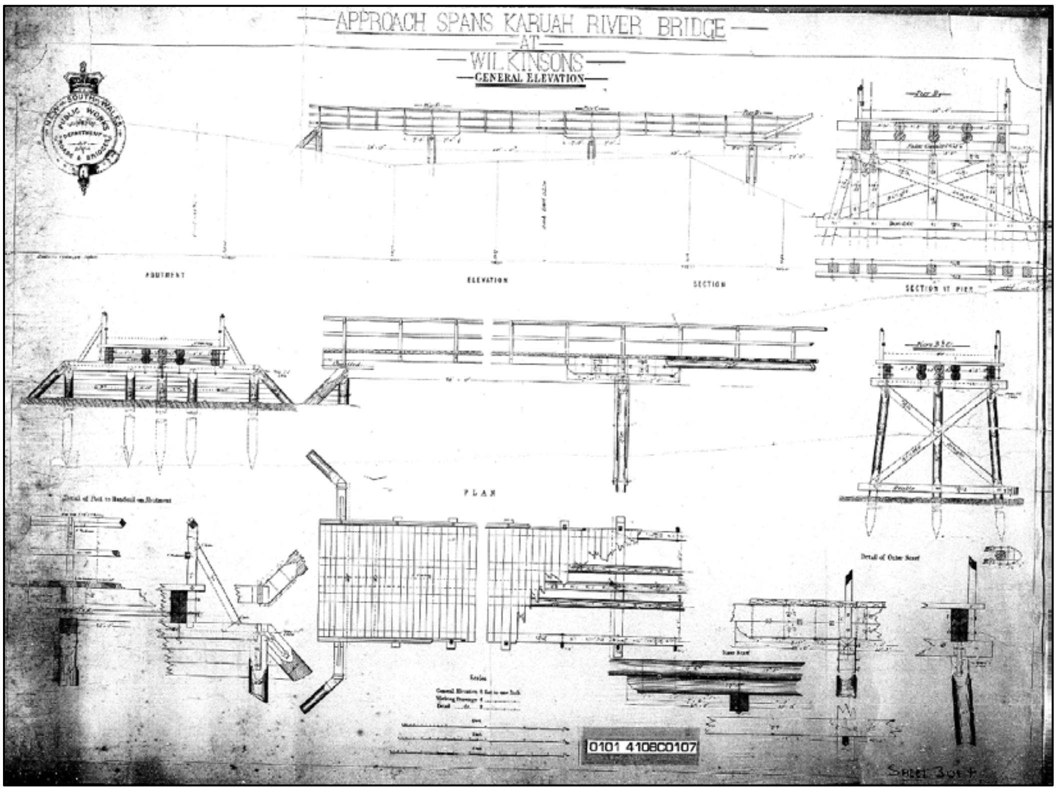
Figure 2-32: Extract from the "Blue Book".



(source: Roads and Maritime, Bridge Engineering)

Figure 2-31 and Figure 2-32 show two different undated configurations of the Monkerai Bridge approach spans. The first shows three different approach span lengths of 40'5", 40'0" and 29'8" (12.32 m, 12.19 m and 9.04 m), and the second shows two span lengths of 40'5" and one of 29'8". Neither of these match what is shown in the original design drawings (Figure 2-33) which indicate approach spans of 28'0", 40'0" and 40'0" (8.53 m, 12.19 m and 12.19 m). This drawing also gives some details for the approach span piers (which none of the other drawings do), but the drawing is clearly not to scale, the piers being significantly taller than those actually required, and the girder arrangement being drawn at unequal spacing but then dimensioned to show equal spacing.

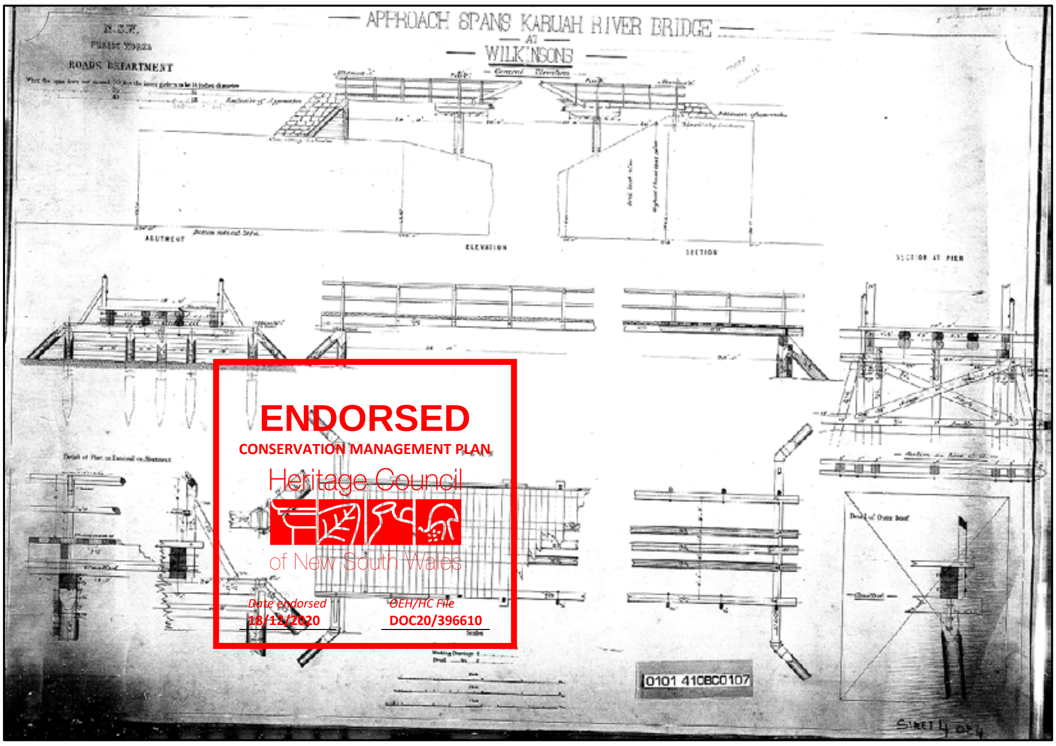
Figure 2-33: Drawings for Approach Spans at Monkerai Bridge.



(source: 0101 410 BC 0107 #3)

The fourth drawing (Figure 2-34) shows another configuration again, which was apparently not used at all. This configuration consisted of an unknown number of truss spans with a single approach span at each end (28', 8.53 m on one side and 20', 6.10 m on the other).

Figure 2-34: Drawings for Approach Spans at Monkerai Bridge.



(source: 0101 410 BC 0107 #4)

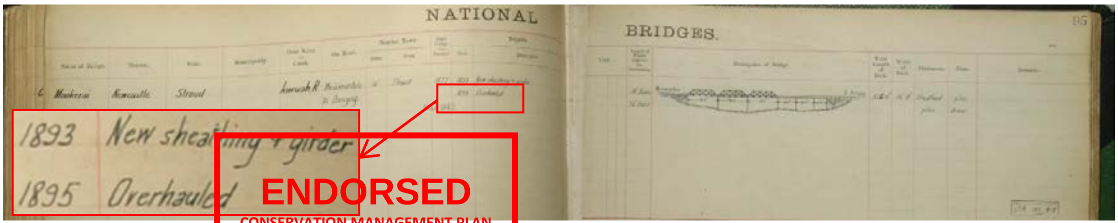
Figure 2-35: First Available undated photograph of Monkerai Bridge.

(source: Roads and Maritime)

2.5 Repair and use of the bridge

There is very little information on the repair and use of the bridge for the first fifty years while it was under the care of the Department of Public Works until it was handed over to the newly formed Main Roads Board (MRB). The only early information is found in the bridge register, otherwise known as the "Blue Book", which is held by Roads and Maritime Bridge Engineering, and contains some errors (eg, date of construction listed as 1877) as well as two maintenance actions, which are simply listed as "1893 New sheathing & girder, 1895, Overhauled" (see Figure 2-36).[88]

Figure 2-36: Extract from the "Blue Book", p 95.



(source: Roads and Maritime, Bridge Engineering)

The Old PWD type timber truss bridges were designed to be replaced rather than maintained, and this is generally what happened. As early as 1895, Percy Allan noted the difficulties in attempting to prolong the life of the Old PWD type truss any way other than complete reconstruction:

> *In all the old types of trusses, the suspension rods* [tension rods] *passed through the floor beams* [cross girders], *and as the braces* [diagonals] *were also butted against the floor*

[88] The Blue Book, Bridge Engineering Section of Roads and Maritime Services, p 95.

beams [cross girders]*, the renewal of these timbers was rendered practically out of the question… Formerly it was the practice to have the top chord in one piece 16" by 14" by 42' long, which having to be bored for the suspension rods* [tension rods]*, rendered renewal very costly, if not impractical… the bottom chord cannot be renewed, thus necessitating in some cases the replacing of the whole structure…* [89]

It does seem unlikely, though not impossible, that the bridge at Monkerai had to be completely reconstructed after less than fifteen years in service (as could be interpreted by the record that it was "overhauled" in 1895), but it is not at all unlikely that it was largely reconstructed some time prior to 1930. The only other remaining Old PWD type timber truss bridge, at Clarence Town, was also completely reconstructed prior to 1930, but the reconstruction of Monkerai Bridge retained most of the original design detailing, whereas significant modifications to top chords, bottom chords and sway braces were introduced at Clarence Town, due to the impossibility of obtaining the correct sizes of timber for the 100' (30.48 m) spans of the Clarence Town Bridge in the 1920s

About this time, F. Laws, who was Assistant Bridge Engineer for the MRB stated that:

Even the careful fitting and trimming once practiced to give some distinction to timber structures, are no longer possible in these days of high labour charges. [90]

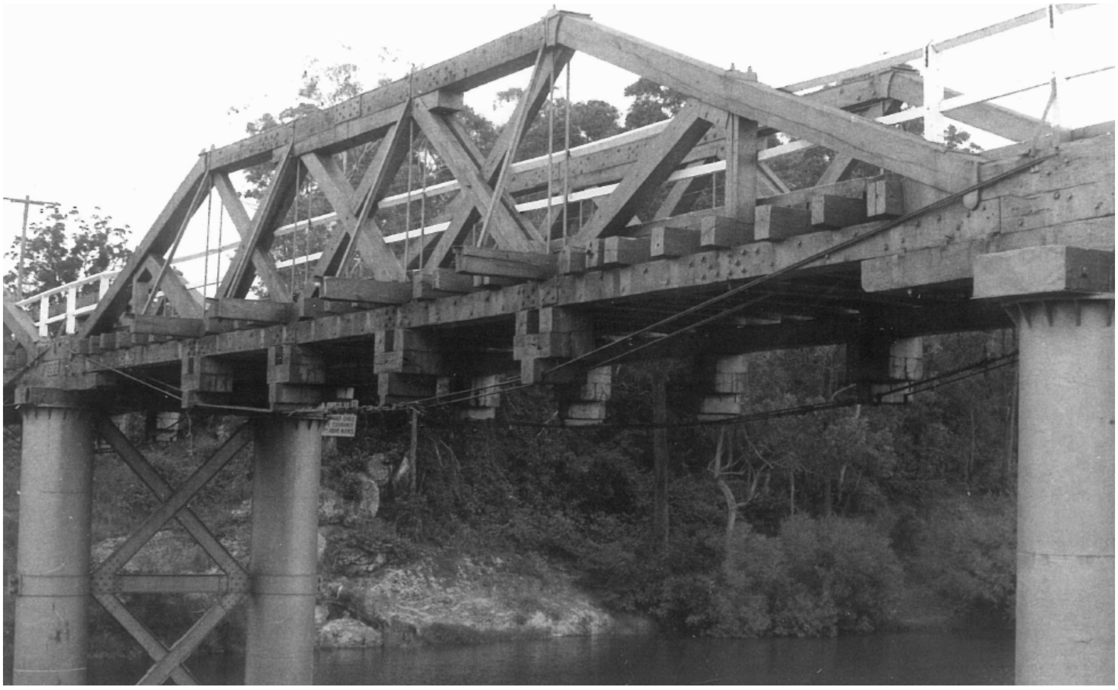
One of the first records on file is from 1933, when an engineer wrote of the bridge:

It has evidently been extensively repaired at various times and quite a large proportion of the original timber has been replaced… the bridge will require either extensive repairs or complete renewal within a few years. [91]

When extensive repairs were carried out, temporary support systems were used so that a piece of timber could be removed and replaced without the bridge collapsing. Very involved systems of poles and wires were sometimes used as can be seen in Figure 2-38. Often, Old PWD trusses would be under-trussed with steel cables (Figure 2-37) as a temporary measure in order to allow traffic to cross despite deterioration of timber truss members. This was, in part, due to the difficulty in replacing timbers. Before Bailey bridging became available, the only way to replace deteriorated bottom chords in Old PWD trusses was to drive piles along the span and erect temporary falsework from underneath to support the bridge while the bottom chord was dismantled and replaced. This was dangerous if a flood occurred, which could cause the bridge along with its temporary support system to collapse, and it was also time consuming and expensive. Bailey bridging therefore increasingly became an important part of timber truss bridge maintenance.

[89] Percy Allan, "Timber Bridge Construction in New South Wales", 1895, pp III, IV, VI.
[90] F. Laws, "Application of Timber and Concrete to Moderate Span Highway Bridges", *Main Roads*, Vol III, No 8, April 1932, p 126
[91] Paper on file 6/2/1933, 410.62 Part 1 cited in RTA, *Conservation Management Plan, Monkerai Bridge*, Draft 25 June 2003 p 8.

Figure 2-37: Clarence Town Bridge, 1974 under-truss.



(source: Roads and Maritime File 128.63-1)

Figure 2-38: Typical Temporary Support System for an Old PWD truss when Bailey unavailable.[92]

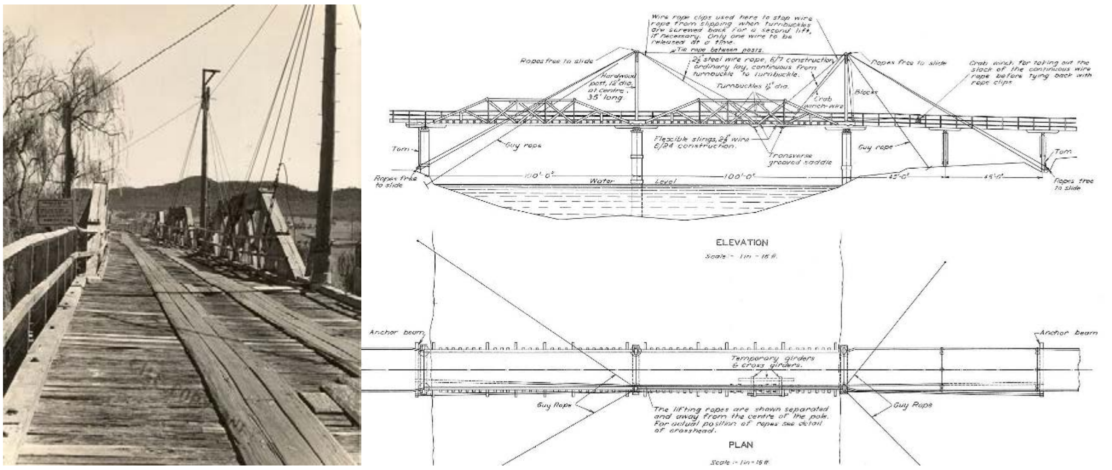


Figure 2-38 also shows a typical detail which was introduced in the 1950s due to the fact that the transverse and diagonal decking had become increasingly unsatisfactory under motor traffic because the planks loosen by the driving wheels, and the consequent looseness and uneven riding surface in turn shake the entire structure of the bridge, loosening other members and causing noise when vehicles cross.[93] In an attempt to mitigate these problems, two sets of longitudinal running strips were placed on the deck under the wheel paths (Figure 2-38). This was done at Monkerai Bridge in the early 1960s, where longitudinal sheeting of the bridge, four planks wide for each of two running strips was completed using second hand timber as it became available.[94]

Prior to the addition of longitudinal running strips, kerbs had been introduced to the deck, as can be seen from Figure 2-39 (left), which is a view of the bridge in 1954 (compare with Figure 2-35). Also in Figure 2-39 (right) is a view of the bridge in 1968, showing that longitudinal

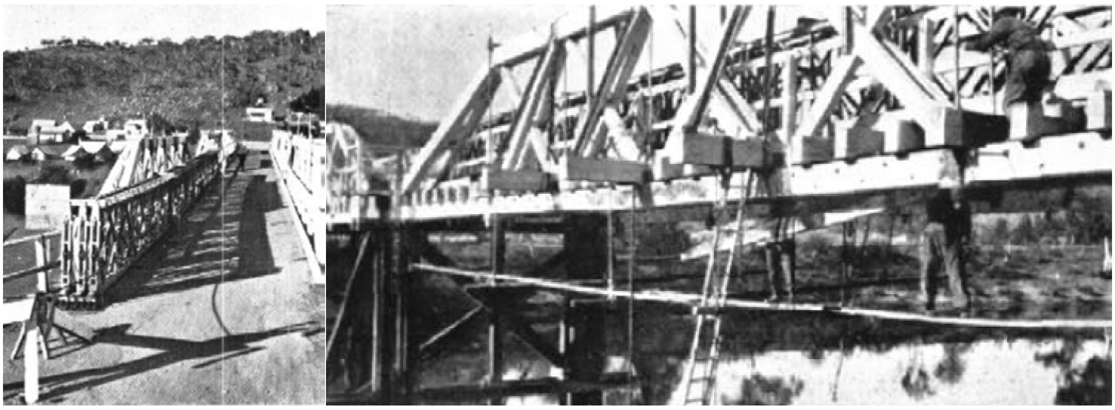
[92] Source: (left) Roads and Maritime file 305.112 (right) DMR, Manual No. 6 Bridge Maintenance, 1962.
[93] "Longitudinal Sheeting of Timber Bridge Decks", *Main Roads*, Vol. 27, No. 4, June 1962, pp 123-124
[94] General bridge file 410.62

sheeting had been provided for the full width of the deck rather than being confined to only two running strips.

Figure 2-39: Photographs of the bridge showing modifications to deck (left 1954, right 1968).[95]

By the late 1940s, Bailey bridging became available and was successfully used to provide temporary support to timber truss bridges during member replacement. The Bailey Bridge, named after its designer, was developed in England during the Second World War and was extensively used by the British and American armies in their advance through France and Germany. It consists of a steel truss built up of rectangular panels connected together, with increased capacity obtained by the use of two, three or four trusses placed alongside each other (Figure 2-40).[96]

Figure 2-40: Bailey Bridging supporting Timber Truss at Jindabyne during repairs in 1947.[97]



A memo of October 1967 records installation of Bailey Bridging to assist in the “restoration of camber and uprightness in each truss” as well as replacement of all tension rods with larger diameter tension rods, presumably in accordance with Maintenance Manual #6, 1962:[98]

> *The suspension bolts in the older trusses being lighter than those now in use, and not having so good a bearing on the chords and principals, may be unequal to the task of restoring camber to the truss in screwing up, therefore, shores should be placed under the chord, which can then be wedged up while the suspension bolt is tightened. If the bolts are damaged they are to be replaced by new bolts 25 per cent. heavier*.[99]

This indicates that the tension rods at Monkerai Bridge are not original fabric, having been replaced with larger diameter tension rods approximately fifty years ago to facilitate cambering.

[95] General bridge file 410.62
[96] *Main Roads*, Volume XII No. 3 March 1947, p 84.
[97] Source: Main Roads, Volume XII No. 3 March 1947, pp 84-85.
[98] General bridge file 410.62.
[99] Department of Main Roads NSW, *Manual No. 6 Bridge Maintenance*, 1962, p 7.

The loss of camber in Old PWD type trusses (as shown in Figure 2-41 below) is a typical problem experienced by this type of truss due to excessive shrinkage of timbers, especially the primary cross girders. Whereas originally, these bridges were constructed of the highest quality timbers, by the end of the 1800s, these timbers were no longer available, and so younger trees (less than 200 years old) had to be cut in order to obtain timber to replace deteriorated members. These timbers sourced from younger trees tend to experience significantly more shrinkage in the long term than the original timbers did, independent of how long they are seasoned prior to installation.

Figure 2-41: Before elimination of truss sags in 1967.

(source: Roads and Maritime File 410.62)

Another typical problem experienced by the Old PWD trusses is described in the same manual:[100]

> *At the junction of the top chord and principals, the shoulder shoes are in most cases fitted with wrought-iron washer plates, through which the suspension bolts pass. As the timber in top chord shrinks from under them these plates become bent, in some cases breaking the cast-iron shoulder shoe. The surface of the washer plate being no longer level, nor at right angles to the suspension bolt, the plate acts as a washer on the cant, and bends the suspension bolt under the nut, tending to break it off. The weight should be taken off the suspension bolt… The bent washer plate should then be cut through with a cold set where it joins the shoulder shoe. This will permit it to drop on to the top chord where it will lie level.*

Surprisingly, there is no evidence that this recommended treatment was applied at Monkerai.

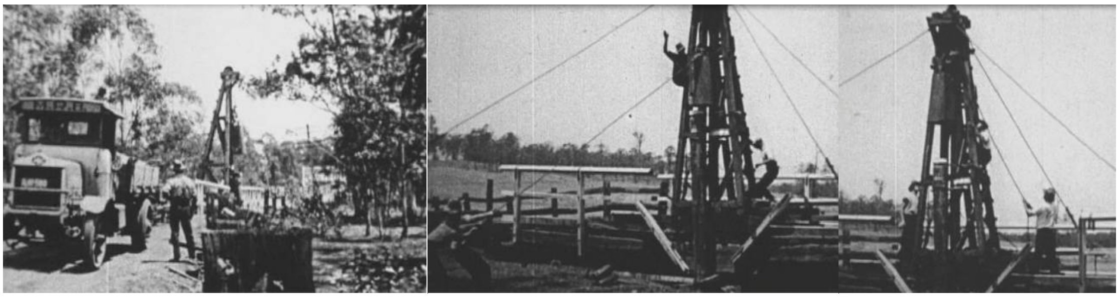
Figure 2-35 indicates that the cast iron shoes had been painted white (or at least a very light colour) rather than black by the time the earliest available photograph was taken (probably in the 1930s, at least 50 years after original construction). The photographs of Monkerai Bridge from the 1950s and 60s still show no colour distinction between the timber and metal components. From Bennett's own photographs of Old PWD trusses, it can be seen that the metal components were generally originally painted black (or at least a very dark colour), and the timbers at least above deck level, and sometimes including the bottom chords were painted white (or at least a very light colour).[101] This change of aesthetic was further exacerbated by bottom chord modifications.

[100] Department of Main Roads NSW, *Manual No. 6 Bridge Maintenance*, 1962, p 8.
[101] Photographs of Roads and Bridges. W.C. Bennett M. Inst. C.E., Y3086F.

A memo of July 1964 reveals that the bottom chord was not in its original configuration by that time.[102] The original configuration consisted of bottom chords 12" x 12" (304 x 304 mm) made up of three laminates of 12" x 4" (304 x 102 mm). Although Spans 5 and 6 (then called Spans 1 and 2) still had bottom chords consisting of three rows of laminates, the bottom chords were 12" x 15" (304 x 381 mm) made up of three laminates of 12" x 5" (304 x 127 mm), and the Span 3 bottom chords were 12" x 16" (304 x 406 mm) made up of four laminates of 12" x 4" (304 x 102 mm). It is not clear from the records when these modification were made, but they are a substantial modification from the original design intent, which provided for the top chords, bottom chords and principals to all be of the same cross-sectional dimensions, thereby framing the truss, and also allowing the neat and aesthetically pleasing cast iron shoes to stand out as a visual feature.

The elements in timber bridges which are the quickest to deteriorate are often the timber piles, which are very susceptible to rot and termite attack in the region just below the ground surface. For this reason, installation of new piles is a critical and regular aspect of bridge maintenance.

Figure 2-42: Main Roads Board Driving Timber Piles in the 1920s and early 1930s.[103]



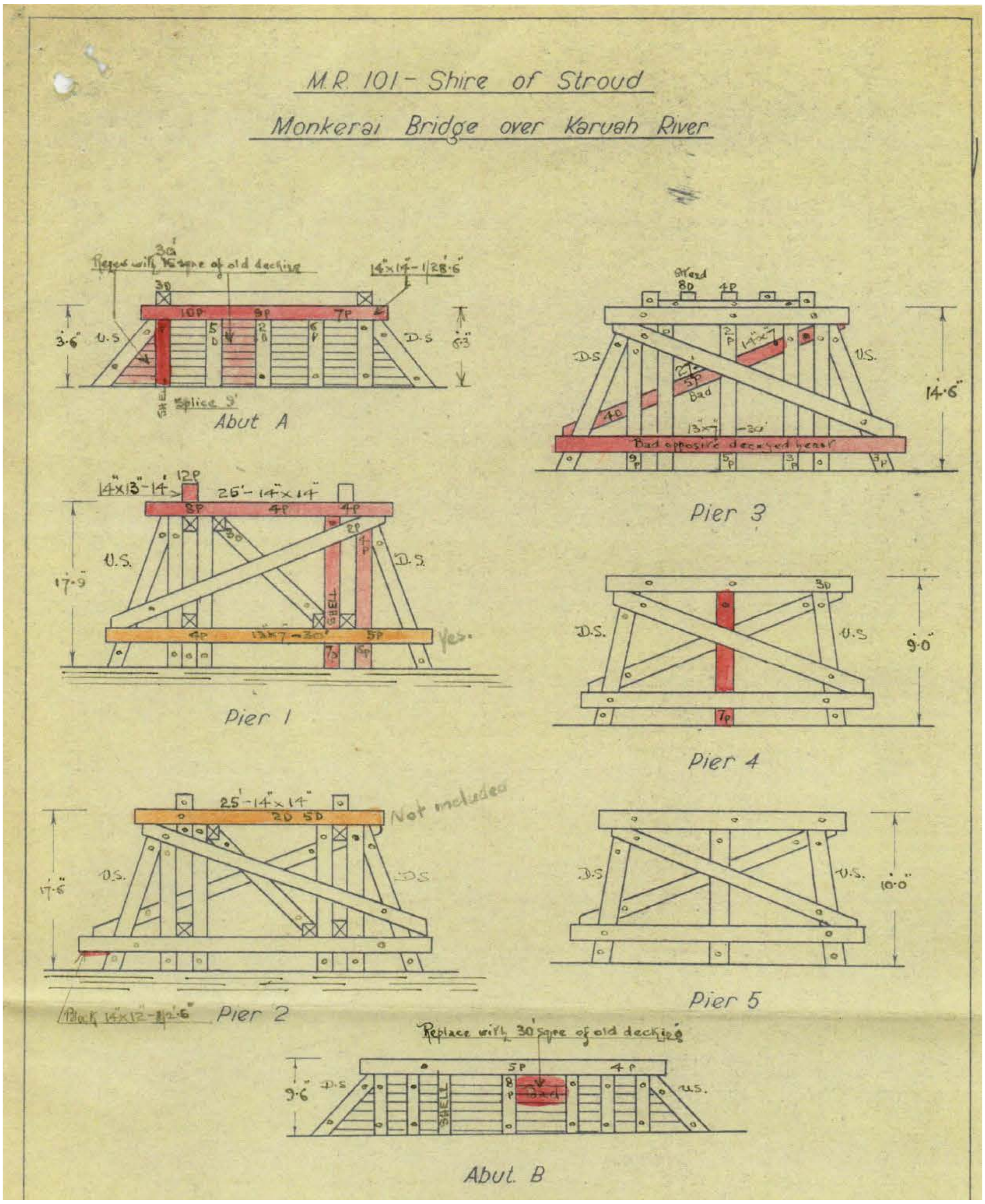
Although it is generally stated that there is no "original fabric" when it comes to timber in bridges, this only applies to visible and accessible fabric. The timber piles well below ground level are almost certainly the original timber piles driven there in the very early 1880s. The current timber piles seen above ground level would be spliced to those original piles by an underground connection. These buried splices do not have the original capacity or durability and therefore pose a significant risk to the bridge. Timber piles rot below ground level and are impossible to replace as a "like for like" replacement or as a restoration of the original because, before a new timber pile can be driven, the old timber pile would have to be removed, and this is generally not possible.

Of all the details of the bridge, the original details of the piers and abutments are the least certain. Although we have good early photographs and design drawings for the top of the bridge, we have neither photographs nor drawings for the piers or abutments as constructed. There are inspection diagrams on file from 1938 and 1944 (more than fifty years after construction) which show the arrangement and heights of the piers and abutments at those times (Figure 2-43). The earliest photograph of the underside of the bridge was taken more than 85 years after original construction.

A memo of July 1964 notes that two piles in Pier 5 (then Pier 1) have concrete around the base. It was common practice as early as the 1930s to attempt to strengthen timber splices by adding concrete. In 19[illegible] Pier 4 (then Pier 2) was completely reconstructed on a new reinforced concrete pile cap. In 1993 Abutment Repairs were undertaken which involved splices to the timber piles with metal side plates and concrete sleeves buried at least a metre below ground level.[104]

[102] General bridge file 410.62.
[103] Source: Roads and Maritime, Oral History Program, Maintaining the Links: Maintenance of historic timber bridges in NSW, 2001.
[104] General bridge file 410.62.

Figure 2-43: 1944 inspection diagrams.



(1938 similar, source: Roads and Maritime file 410.62)

By the year 2000, there was a noticeable asymmetry of the trusses when looking along the bridge due to deterioration and slippages of timber. While some truss top chords were almost 100mm higher than original, others were more than 200mm lower than original. This loss of geometry was probably the cause of a large number of cast iron shoes being found broken, and it also meant that it was impossible to restore the correct geometry by replacing timber elements one at a time. This deterioration is despite the fact that considerable repair work was carried out between 1993 and 1995 including repainting, replacement of a top chord, some principals, parts of the bottom chord, a large number of cross girders and many elements from the approach spans and piers.

In June 2000, one of the timber trusses failed under traffic, so a Bailey was put in place in order to repair the broken principal and bottom chord, during which the bridge was subjected to a 5t limit. Monkerai Bridge was subsequently closed to all vehicular traffic on 7 April 2004.

Figure 2-44: Failure of Principal and Bottom Chord in June 2000.

(source: Roads and Maritime)

The closure of Monkerai Bridge left no high level crossing for landlocked residents and businesses. Riverwood Downs was the largest local business affected by the Bridge closure, with 24 staff, an average of 200 guests per night, and a maximum capacity of 1000. In the event of a flood, emergency services would be unable to reach this business by road, posing an unacceptable risk to residents and public. Monkerai Bridge could not quickly be reopened due to difficulties in obtaining timbers as well as the need to gain heritage approvals not only for the design but also for the construction methodology because the bridge required a complete reconstruction. Therefore, an appropriate alternative route for public and residents was made safe and available, this being Dixon's Crossing, which was a low level causeway located approximately 2km upstream of Monkerai Bridge. The crossing had been constructed in the early 1960s to replace a failed timber bridge and this was replaced in 2005 with a concrete culvert constructed at a higher level for flood immunity in a 1 in 2 year flood (compared to Monkerai Bridge, designed to clear the highest known flood at the time of design). Dixon's Crossing continues to provide the primary detour today.[105]

The table below provides a summary of all the reported maintenance works undertaken. Much of the work undertaken appears not to have been reported, and the work that has been reported was not reported in sufficient detail to enable accurate dating of individual elements of timber remaining in the bridge, or even to get an accurate picture of how long timber lasts prior to replacement.

[105] Completion Report, Monkerai Bridge Detour – Dixon's Crossing Upgrade November 2004 to May 2005, General bridge file 410.62.

Year	Summary of maintenance work undertaken [106]	Reported Cost
1882	Construction Completed	£ 2,000
1893	New sheathing and girder	
1895	"Overhauled"	
1938	Piers 4 and 5 are shown in an inspection diagram to have differing bracing arrangements at it is highly unlikely that these two piers were originally different, so Pier 5 had been significantly modified by this date	
1954	Kerbs had been added to the bridge by this stage, as evidenced by photos, and the colour scheme had also been modified with the metal components painted the same shade as the timber components	
1963	Began to add longitudinal running strips, four planks wide each, to the deck of the bridge using second hand timber as it became available	
1964	Original bottom chord laminate layout (12"x 12" made from three rows of 12"x4") had by this stage been replaced with 12"x15" (3/12"x5") on two of the truss spans and 12"x16" (4/12"x4") on the other truss span, thereby also indicating a loss of continuity over the piers, definitely at Pier 4 and probably also at Pier 5 due to lack of understanding of design. Also by this stage two piles in Pier 1 (now Pier 5) have concrete around the base	
1967	Replacement of all wrought iron tension rods with new larger tension rods while bridge is supported on Bailey, restoration of camber and alignment, longitudinal sheeting had been added to the bridge for the full length and width of the deck by this stage, as evidenced by photographs.	$ 3,500
1979/80	Bailey Bridge installed for truss repairs	$ 21,832
1980/81	Primary cross girders replaced in Spans 3 & 4 with Bailey, new Pier 2 (now Pier 4) constructed on 10m x 1m x 1m reinforced concrete base.	$ 13,188
1981/82	Bailey installed, emergency works, longitudinal sheeting	$ 18,212
1984/85	Major repairs including 2 primary cross girders	$ 49,237
1985/86	Major repairs including 2 primary cross girders with Bailey to remove bridge from list of "structurally deficient bridges"	$ 117,563
1992	Material procured for 6 primary cross girders, 15 t load limit	$16,000
1993	4 primary cross girders replaced and Abutment A repaired with introduction of concrete sleeves at splices buried more than 1m u/g	$ 122,000
1994	6 primary cross girders replaced	$180,000
1995	Truss repairs with Bailey, photographs on file from 1995 indicate that by this time, the original timber sway bracing had been replaced with metal sway bracing on extended primary cross girders, some extended by additional length and others by metal attachments bolted to the timbers	$ 3,600
1997	1 primary cross girder replaced	$ 38,500
2000/01	Span 5 truss failure, bailey installed	$ 400,000

[106] As recorded in "the blue book", noted from photographs or recorded in the general bridge file 410.62.

Year	Summary of maintenance work undertaken [106]	Reported Cost
2001/02	Bailey and design	$ 263,500
2002/03	Bailey and design	$ 141,300
2003/04	Bailey and design	$ 353,000
2004	Bridge closed to traffic, an alternative crossing 2km upstream has been provided, since which regular inspections have continued to be undertaken as well as propping of the bridge from below, but no replacements of deteriorated elements or painting of the structure	

2.5.1 The bridge today

The Monkerai Road route is still of substantial importance to the local and regional community, as can be seen from recent Council efforts to upgrade the road. Although it is still a very narrow, windy and unsealed road, two of the small timber bridges (single lane bridges over Sugarloaf Creek and over Scooters Creek) were replaced as recently as 2015 with new concrete bridges.[107]

In preparation of an earlier CMP (2003), never completed, a letter was written to the Stroud and District Historical Society asking if there was any information in the Society's records on the early history of the Bridge. A response was received from the Society which stated that the Society had very little information regarding the Bridge and no records or photographs relating to its early history.[108] That CMP also recorded that the local residents knew that the bridge was old, but that it did not have any particular social significance, other than fulfilling its role for them as a road bridge.

More recently in 2011, Roads and Maritime has undertaken an extensive program of consultation regarding all the timber truss road bridges throughout the State. The few public submissions received for Monkerai Bridge were in favour of its retention. The submissions against retaining the bridge point out that it has hindered development in the valley, disadvantaged landholders on both sides, and created operational and logistical difficulties for businesses in the district.[109]

For the last thirteen years, the bridge has been closed to vehicular traffic, and no longer performs any function for the local community other than carriage of pedestrians. The most recent bridge inspection on file, dated 23 November 2016, records that it is in a very poor and deteriorated condition.[110] The bridge is propped with various additional timber props supported on the ground.

[107] VEC Civil Engineering Pty Ltd, Marketing brochure, 6x Council Bridges Great Lakes Council, from www.vec.com.au (accessed 1 June 2017).
[108] RTA, *Conservation Management Plan, Monkerai Bridge*, Draft 25 June 2003 p 8.
[109] Roads and Maritime, *Timber Truss Bridge Conservation Strategy, Submissions Report and Revised Conservation Strategy*, August 2012, ISBN 978-1-922194-17-6, p 30.
[110] Roads and Maritime, Bridge Inspection Report – Level 2 – Bridge No 1477, 23 November 2016 (BIS).

3. Documentary and physical evidence

3.1 Analysis of the existing fabric

3.1.1 Definitions of condition states for a timber truss bridge

Reference is made in this Section to an inspection carried out by Roads and Maritime on 23 November 2016.[111] This is the most recent of the regular inspections undertaken by Roads and Maritime in accordance with the Bridge Inspection Procedure Manual.[112] In this inspection, each element of a bridge is given a "condition state" and these are defined in the following tables.[113]

Condition State	Timber Elements of Timber Trusses – Condition State Descriptions
1	The timber is in good condition with no evidence of decay. There may be cracks, splits and checks having no effect on strength or serviceability. All connections are in good condition and bolts are tight.
2	Minor decay, insect infestation, splitting, cracking, checking or crushing may exist but none is sufficiently advanced to affect serviceability. Joint connections may be slightly loose but does not affect the serviceability.
3	Medium decay, insect infestation, splitting, cracking or crushing has produced loss of strength of the element but not of a sufficient magnitude to affect the serviceability of the bridge. Joint connections may be slightly loose but the serviceability of the bridge is not significantly affected.
4	Advanced deterioration. Heavy decay, insect infestation, splits, cracks or crushing has produced loss of strength that affects the serviceability of the bridge. Connections are very loose causing large movements, bolts are corroded and ineffective or missing, and the serviceability of the bridge is affected.

Condition State	Metal Tension Rods in Timber Trusses – Condition State Descriptions
1	The camber of the bottom chord is correct. There is no evidence of section loss.
2	The camber of the bottom chord is correct. Surface rust or minor pitting has formed or is forming. There is no measurable loss of section. There may be minor deformations that do not affect the integrity of the element.
3	Tension rods may need to be tightened to restore camber of bottom chords. Heavy pitting may be present. Some measurable section loss or necking is present locally. There may be missing locknuts but all connectors are in sound condition.
4	Tension rods may need to be replaced to restore camber of bottom chord. Significant section loss may be present. The tension rods may have stretched.

[111] Roads and Maritime, Bridge Inspection Report – Level 2 – Bridge No 1477, 23 November 2016 (BIS).
[112] Roads and Maritime, *Bridge Inspection Procedure Manual*, second edition, June 2007.
[113] Roads and Maritime, *Bridge Inspection Procedure Manual*, 2007, chapter 4 (Timber), pp 2, 24, 36.

Condition State	Metal Shoes in Timber Trusses – Condition State Descriptions
1	There is no evidence of section loss or damage or cracks.
2	Surface rust or minor pitting has formed or is forming. There is no measurable loss of section. There may be minor deformations that do not affect the integrity of the element. There are no cracks in the metal. All connectors are in sound condition.
3	Heavy pitting may be present. Some measurable section loss is present locally. There may be minor cracks and/or deformations in the steel or welds. All connectors are in sound condition.
4	Significant section loss may be present. There may be cracks and/or deformations in the steel or welds. There may be numerous failed connectors.

3.1.2 Definition of heritage integrity for a timber truss bridge

Heritage integrity (sometimes called intactness) in the case of a timber truss bridge is best defined as the extent to which the existing elements are consistent with the original design in form, fabric and function.

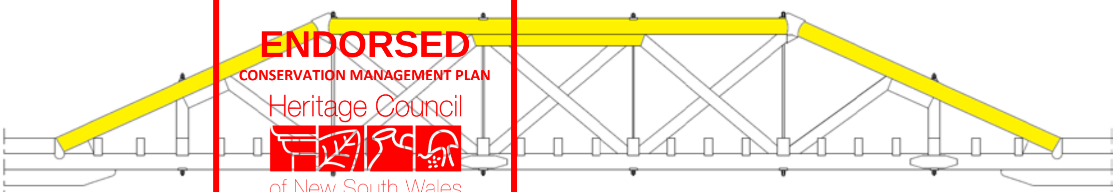
- The **form** includes the general shape of the truss as viewed from a distance as well as the shapes and sizes and interactions of the various components of the truss viewed close up.
- The **fabric** includes the type of material as originally specified, whether it be New South Wales hardwood, metal, masonry or concrete (not necessarily the age of the material).
- The **function** includes the general use of the bridge to carry traffic, enable industry, open up land and connect communities as well as the particular structural function of an element (eg, compression or bending member, shear connection, etc.).

For this reason, in order to assess the heritage integrity of this timber truss bridge, the following pages examine each element as it compares with the original. For each element, there is a detailed description of the original and a description of how the existing varies from the original due to modifications, and comments on condition. A summary of the condition and integrity of each element is given in Section 3.2.

3.1.3 Truss span top chords and principals

The timber top chords and principals are highlighted in Figure 3-1 below.

Figure 3-1: Original 70' Old PWD design with top chords & principals highlighted.



(source: author)

Original Design

The original dimensions of the primary top chord timbers were 12" x 12" x 29'6" (304 x 304 x 8992 mm). The original dimensions of the additional central top chord members were 12" x 9" x 11'0" (304 x 230 x 3352 mm). The original dimensions of the principals were 12" x 12" (304 x 304 mm). Each of these timbers was originally a single solid piece of timber, most probably ironbark.

Existing Condition

None of the timbers in the top chords or principals are original fabric, but they are NSW hardwood. According to the most recent inspection (Figure 3-3) five of the six primary top chord timbers are rated as condition state 4, and one as condition state 3. Three of the six additional central top chord timbers are rated as condition state 4, two in condition state 3 and one in condition state 2. Eight of the 12 principals are rated as condition state 4, one in condition state 3, two in condition state 2 and one in condition state 1. This indicates that almost all the timber is very poor condition.

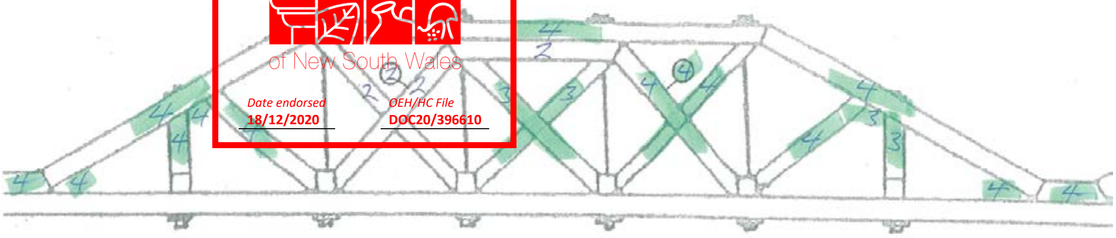
Analysis of Modifications

All of the top chord timbers consist of single solid timbers as per the original design. However, two of the principals, both in Span 5, have been replaced with two timbers spliced together with bolted metal side plates. This modification does not reflect the original design intent and detracts from the structural integrity and the heritage integrity of the truss. The top chords and principals vary significantly from the original dimensions, with lengths of top chords varying by approximately 115 mm and lengths of principals varying by approximately 140 mm again detracting from integrity.

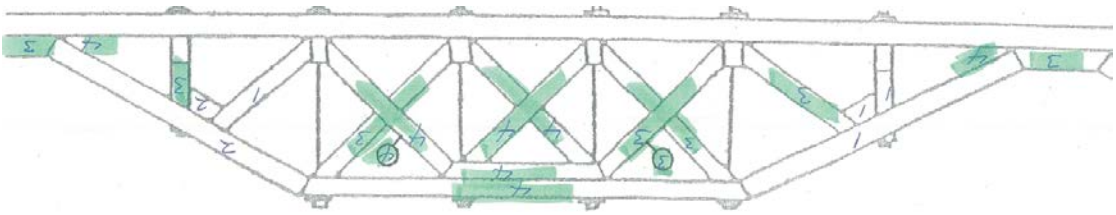
Figure 3-2: Photo of metal side plate and additional bolts on principal.

(source: author 2017)

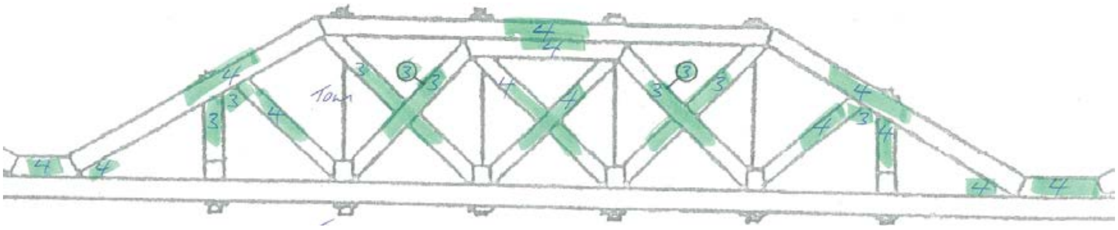
Figure 3-3: 2016 inspection condition ratings for truss spans.



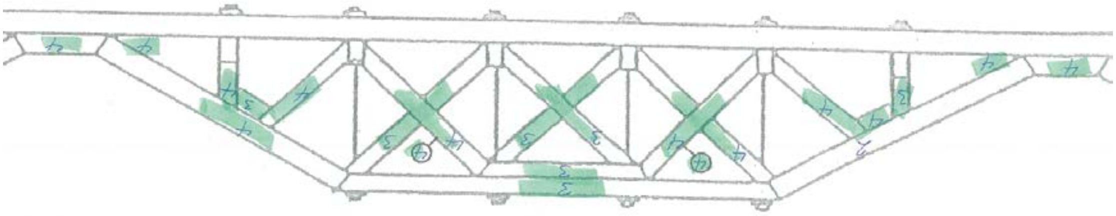
Span 4 Downstream



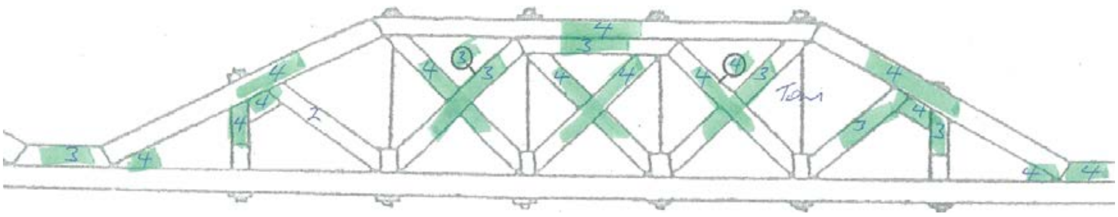
Span 4 Upstream



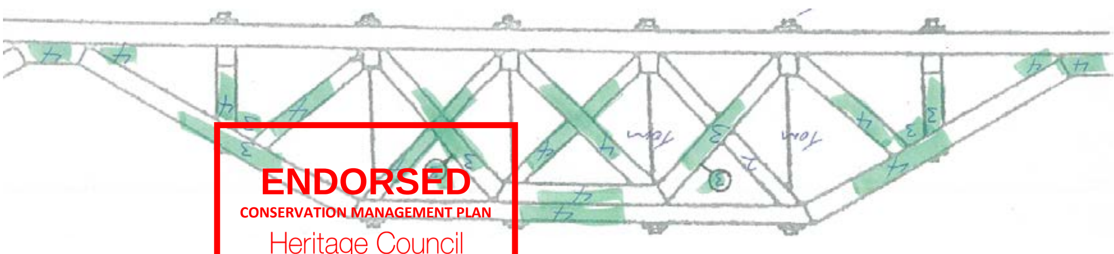
Span 5 Downstream



Span 5 Upstream



Span 6 Upstream



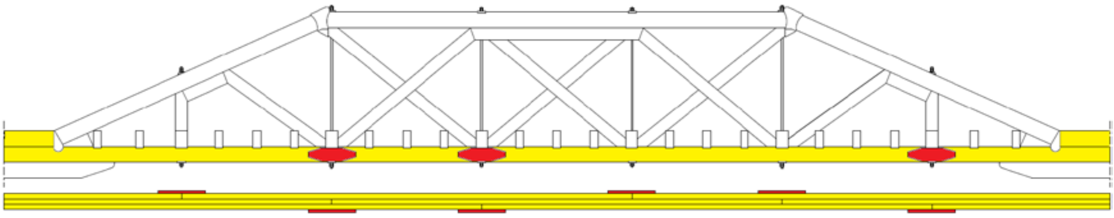
Span 6 Downstream

(source: Roads and Maritime)

3.1.4 Truss span bottom chords and butting blocks

The bottom chord and butting blocks are shown in elevation (top) and plan (Figure 3-4). The timber laminates and butting blocks are yellow and the metal elements (fish plates) are highlighted in red.

Figure 3-4: Original 70' Old PWD design with laminate layout of bottom chord.



(source: author)

Original Design

The original bottom chords consisted of three rows of timber laminates each 12" x 4" (304 x 102 mm) bolted together to form a continuous timber bottom chord across all three truss spans of 12" x 12" (304 x 304 mm). Joints in the timber laminates occurred only at panel points, and were provided with metal fish plates (highlighted in red in Figure 3-4 above) to ensure correct bolting arrangements at the joints. Butting blocks provide the primary load path between the principals and the bottom chords, and consisted of single solid pieces of timber each 14" x 12" (356 x 304 mm) notched down to 12" x 12" (304 x 304 mm) to key into the timber bottom chord laminates.

Existing Condition

The bottom chord contains no original fabric, either of timber or of metal. All bottom chord and butting block timbers were given a condition rating of 3 or 4, indicating very poor condition.

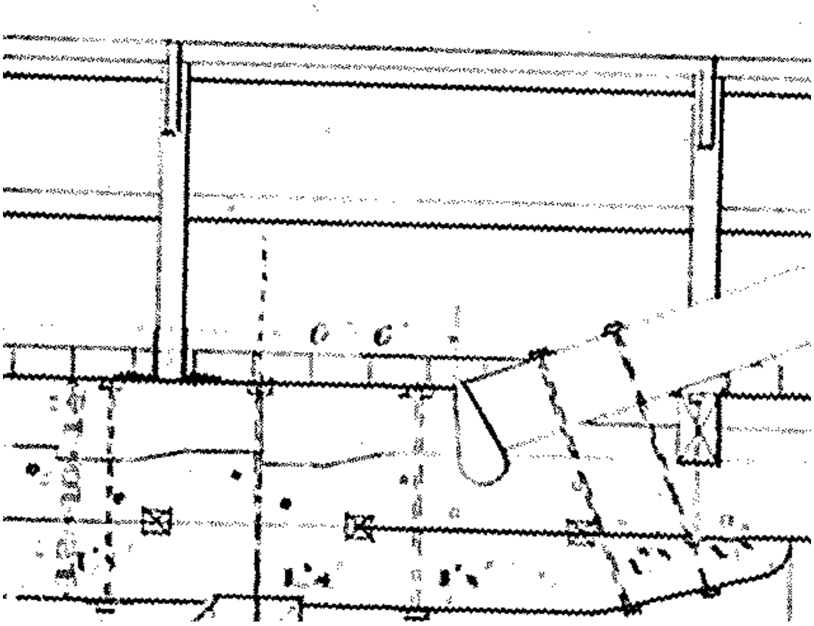
Analysis of Modifications

Neither the bottom chords nor butting blocks reflect the original design intent:

- Originally the outer dimensions of the bottom chords were the same as the outer dimensions of the top chords and principals (12" x 12" or 304 x 304 mm). Currently the bottom chords are considerably larger than the top chords and principals.
- Currently the Span 4 bottom chords have an additional row of laminates making four rows.
- Originally, there was a minimum of 9'6" (2896 mm) between joints in the bottom chord laminates. Currently, some joints are spaced very close together (less than 500 mm)
- Originally the laminates were continuous over the piers and now they are not.
- Originally there were wrought iron fish plates at each panel point, which are now missing. Steel splice plates have been added at some locations, but not at original locations. Some of these steel splice plates are very large, and none retain the original bolting configuration.
- Originally there was a keyed connection between the bottom chords and butting blocks. The original shoulder has been partially retained at some locations, but the load paths are largely ineffective due to modifications and the keyed connections have been completely lost at most locations.
- Originally there were timber shear keys at the interface between the bottom chords and the corbels. These are now missing, although at three of eight locations the holes remain in the bottom chord timbers indicating where the timber shear keys had been (see Figure 3-5 and Figure 3-6).

- One of the single solid butting blocks has been repaired by removing deteriorated timber only so that now the butting block consists of two pieces of timber.
- Due to all of the abovementioned modifications, the capacity of the existing timber bottom chord (even if it was in reasonable condition) is only a small fraction of the original.

Figure 3-5: Connection Details.



(Source 0101 410 BC 0107 #1)

Figure 3-6: Photo of notches for missing shear keys in bottom chord.

(source: author 2017)

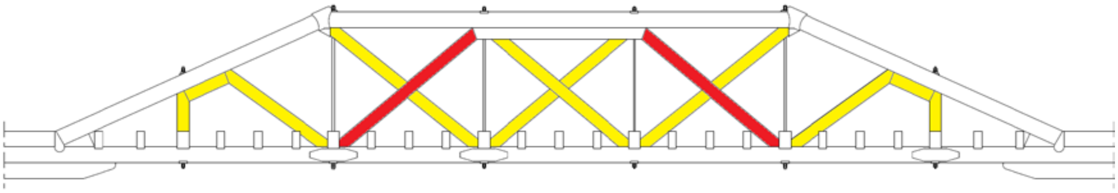
Figure 3-7: Photo showing poor condition and alignment of bottom chord.

(source: author 2012)

3.1.5 Truss span diagonals and props

The timber diagonals and props are highlighted in Figure 3-8 below.

Figure 3-8: Original 70' Old PWD design with diagonals and props highlighted.



(source: author)

Original Design

The original diagonals and props consisted mostly of single solid pieces of timber (yellow in Figure 3-8) with the exception of the first diagonals (highlighted in red) which consist of double timbers bolted together with single bolts at the top and bottom and at the centre where they intersect the opposing diagonal. All diagonals originally had a width of 9" (230 mm) as viewed in elevation. The central panel had diagonals 9" x 8" (230 x 200 mm), each neatly notched to half of its width at the cross-over location to accommodate the opposing diagonal. The double diagonals originally consisted of two timbers each 9" x 6" (230 x 152 mm) bolted together to give a total dimension of 9" x 12" (230 x 304 mm), again with all timbers notched in order to neatly accommodate the cross over. The props under the principal were again single solid timbers 9" x 8" (230 x 200 mm). The vertical timber props had a hole bored through the centre in order to accommodate the tension rod.

Existing Condition

None of the timbers in the diagonals or props are original fabric, but they are still NSW hardwood. According to the most recent inspection (Figure 3-3), almost all (76 out of 84) diagonals and prop timbers were given a condition rating of 3 or 4, indicating that the timber is very poor condition.

Analysis of Modifications

Neither the diagonals nor the props reflect the original design intent:

- Originally the dimensions were such that symmetry was achieved about the centre of the span, but now the lengths and dimensions are irregular and inconsistent.
- Originally the notching of diagonal timbers to accommodate the opposing diagonals was tight and neat and square giving additional robustness to the truss. Currently much of the notching is significantly oversize to accommodate the large movements which have been experienced by the trusses due to their deterioration and loss of strength (Figure 3-9).
- The double timbers were originally bolted closely together to form one piece, whereas currently a number of the double diagonals have been replaced with timbers of smaller cross-section and timber spacers have been introduced at the top and bottom (Figure 3-10).
- Additional timber props have been provided at the northern end of Span 6 which extend from the bottom chord to the top chord and are further supported by timber props below the bottom chord supported directly off the ground to prevent the bridge from collapse.
- A large number of timber and metal wedges have been introduced to fill in the gaps between the diagonals and the primary timber cross girders (Figure 3-13). These gaps have opened up over time due to the shrinkage of the primary cross girders, the loss of original notching designed to keep cross girders in place, and from the loss of structural integrity of the bridge due to substantial bottom chord modifications and deterioration of the timber.
- All of the single solid vertical props located under the principals have been replaced with double timbers bolted together with four small bolts, two at the top and two at the base, probably due to the difficulties in boring the holes for the tension rods (Figure 3-11).

While the trusses are still recognisable as Old PWD trusses and many of the original timber shapes and configurations are still partially present in the diagonals and props, the loss of symmetry and other modifications outlined above do not reflect the original aesthetic or design intent and detract from the structural integrity and the heritage integrity of the trusses.

Figure 3-9: Photo showing oversize notches in timber diagonals.

(source: author 2012).

Figure 3-10: Photo showing gap and spacer introduced in double diagonal.

(source: author 2017)

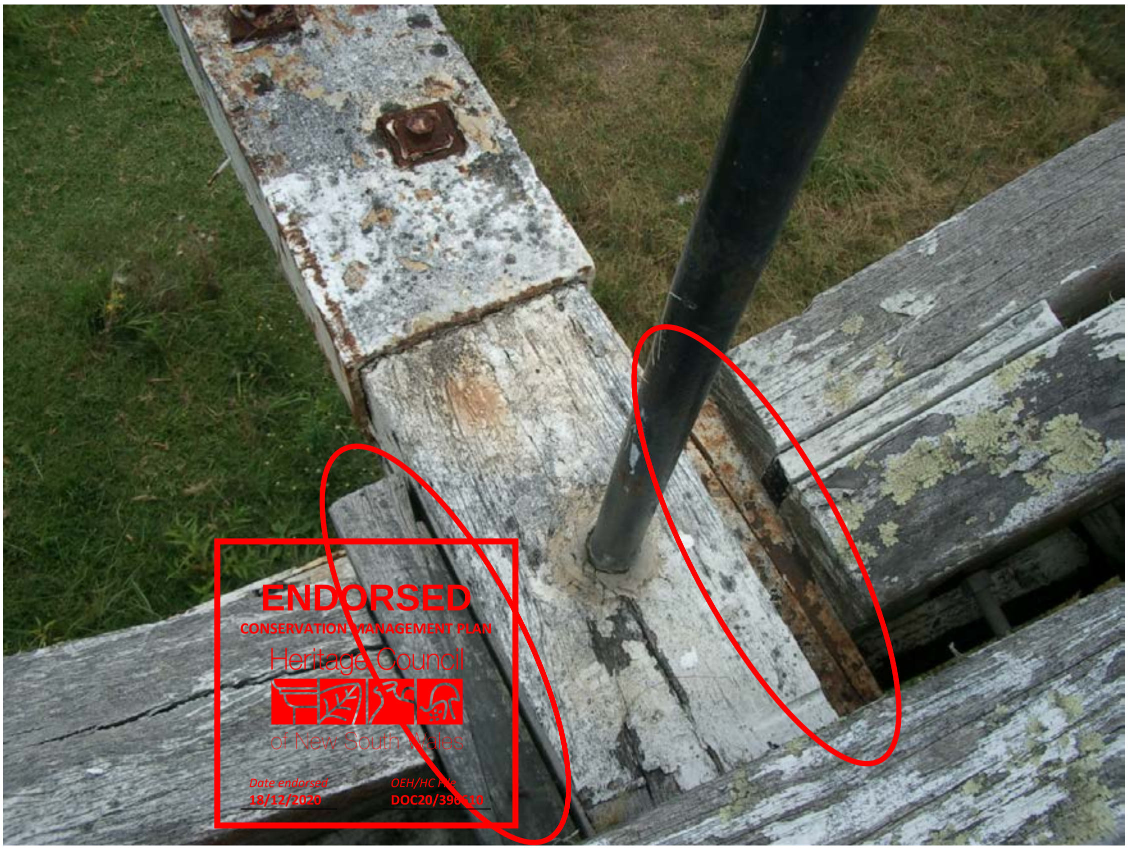
Figure 3-11: Photo showing vertical props consisting of two timbers bolted.

(source: author 2012)

Figure 3-12: Photo of additional timber props and general dilapidation.

(source: author 2017)

Figure 3-13: Photo of additional timber & metal wedges at base of diagonal.

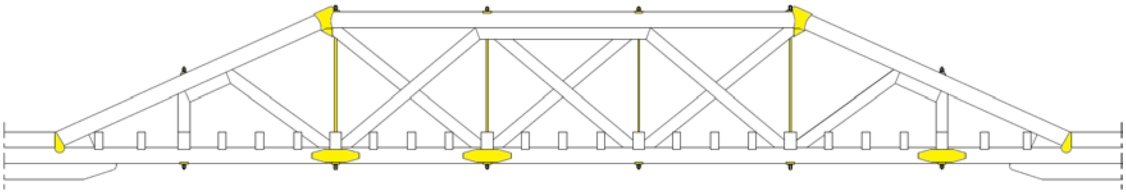


(source: author 2012)

3.1.6 Truss span metal components

The original design included a number of metal components which are highlighted in Figure 3-14 below. These include cast iron shoes at the tops and bases of the principals, wrought iron tension rods at each panel point with wrought iron washer plates provided top and bottom, wrought iron fish plates along bottom chords, and a wrought iron bevelled washers at the tops of the shorter wrought iron tension rods (not to mention the various metal bolts and spikes that were also used).

Figure 3-14: Original 70' Old PWD design with metal components highlighted.



(source: author)

Fish Plates

The original 36 wrought iron fish plates were 3'0" (914 mm) long and 10" (254 mm) wide with tapered corners and six bolts. None of the fish plates remain in form, fabric or function. Fish plates were unique to the Old PWD truss, and so their loss does impact upon the heritage integrity.

Tension Rods

The original 36 wrought iron tension rods came in three different types. The short end tension rods and the long central tension rods were originally 1¼" (32 mm) diameter. The tension rods located at the ends of the top chords are subjected to higher stresses and were originally 1½" (38 mm) diameter. None of the existing tension rods appear to be original fabric. According to the most recent inspection in 2016, almost all half of the tension rods were given a condition rating 4 and the other half had a condition rating of 3, indicating that the metal has suffered serious corrosion.

Cast Iron Shoes

The cast iron shoes at the tops of the principals appear all to be original fabric. There are twelve such shoes (one at each principal), two of which are clearly broken (Figure 3-15), both on Span 4.

Figure 3-15: Photos of typical top chord cast iron shoe.

(source: author 2017)

Figure 3-16: Photos of broken top chord cast iron shoes.

(source: author 2017)

The tear drop shaped cast iron shoes at the bases of the principals are much more difficult to view due to modifications that have been made to the bottom chords, thereby obscuring the shoes. Both the top and bottom shoes were designed to neatly and exactly fit the timbers which were supposed to be 12" x 12" (304 x 304 mm). As can be seen from Figure 3-15, some of the principals and top chords have been replaced with slightly larger timbers and then notched at the ends in a rather unsightly way to fit into the shoes. The situation at the bottom of the principals is worse (see Figure 3-17) because the bottom chords are all significantly wider than designed thereby completely obscuring the tear drop shape of the cast iron shoes in almost all instances. Some bearing blocks are also larger than originally designed, causing what was originally a very neat and aesthetically pleasing connection to be a mess of metal and ill-fitting timber.

Figure 3-17: Photo of tear drop shaped cast iron shoe largely obscured.

(source: author 2017)

Some of the cast iron shoes at the bases of the principals appear to be original fabric, but many of them are broken, and it is not clear whether the bottom of the original shoes has been removed when the bottom chord was first modified or whether the timber is notched to suit. It seems most likely that part of the shoe would have been cut off in order to accommodate the wider bottom chords. Some evidence for this theory is a photograph on record from 2004 showing a broken cast iron shoe which had been removed from the bridge, indicating that one of the tear drop shaped curves had been removed (the cut appears to be too neat to have been caused by fracture). The fracture displayed by this broken shoe (Figure 3-18) is typical of the cracks seen in a number of the remaining shoes. Clearly, if this shoe was removed from the bridge in 2004 then not all of the bottom chord shoes are original fabric. Probably all are either damaged or modified or both.

Figure 3-18: Photo of broken modified shoe removed from bridge.

(source: Roads and Maritime)

Wrought Iron Washer Plates

The wrought iron washer plates at the ends of the tension rods all appear to be original, although some have been slightly modified. There are three different types of wrought iron washer plates:

There is the sliding wrought iron washer plate located at each end of the top chord, on which the double nuts at the tops of the larger diameter tension rods are supported (see Figure 3-19). These wrought iron washer plates were designed to slide into the notches provided in the cast iron shoes. They were originally 1" (25 mm) thick, 14¼" (362 mm) long and 14" (356 mm) wide, notched down to 12" (304 mm) wide for the extension beyond the cast iron shoe. They were tapered at one end to match the slope of the cast iron shoe and had slightly curved edges at the exposed end. They had a hole to fit the original 1½" (38 mm) tension rod, which has since been enlarged to fit the current 42 mm tension rods.

There is a bevelled wrought iron washer at the top of each short tension rod, bevelled to accommodate the slope of the principal (see Figure 3-20). The short tension rods are the only ones which have not been upsized, and in fact some are smaller than the original diameter, and so these bevelled wrought iron washers have not been modified.

Figure 3-19: Photo of wrought iron sliding washer plate in cast iron shoe.

(source: author 2017)

Figure 3-20: Photo of wrought iron bevelled washer and short tension rod.

(source: author 2017)

The third type of washer plate consisted of a wrought iron plate 14” x 6” x ¾” thick (356 x 152 x 19mm) bent up at the corners to snugly fit the 12” (304 mm) top chords and bottom chords. These are located at the base of every tension rod and at the top of the two central tension rods, and they appear to be largely original fabric. These washer plates have been modified to accommodate the larger (36 mm rather than 32 mm) tension rods by increasing the sizes of the holes. Whereas the washer plates originally fit snugly around the timbers, now due to modifications in the sizes of both top chords and principals, the fit can no longer be described as neat, especially at the bottom chords (Figure 3-21 and Figure 3-22).

Figure 3-21: Photo of wrought iron washer plate at top of tension rod.

(source: author 2017)

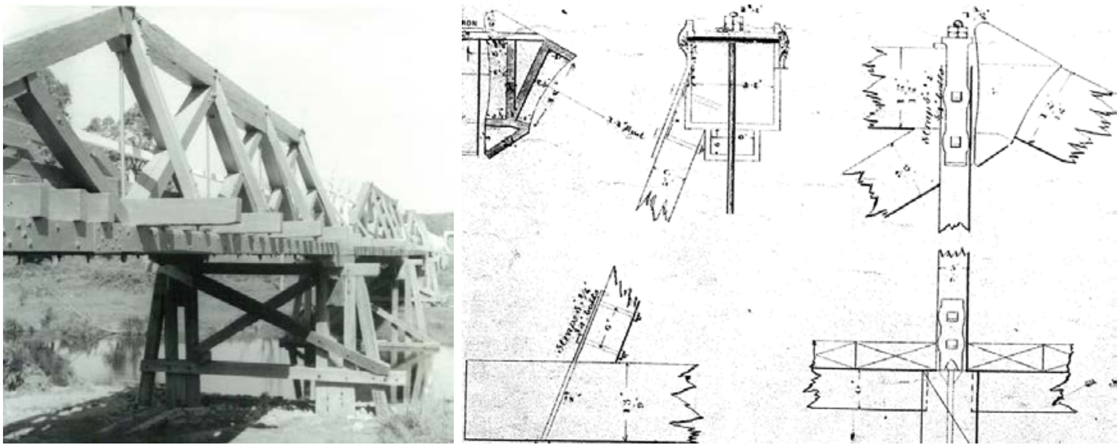
Figure 3-22: Photo of wrought iron washer plate at bottom of tension rod.

(source: author 2017)

3.1.7 Truss span sway braces

Figure 3.31 below shows the original detailing for the sway braces at Monkerai Bridge.

Figure 3-23: Photo from 1960s and original design drawings from 1881 for sway braces.[114]



Original Design

The original sway braces were constructed of 6" x 5" (152 x 127 mm) timbers extending outwards at a steep angle from the top chord and connected at the base to the primary cross girders. They were connected with great care and attention to detail at the top and bottom in order to provide a robust connection in both tension and compression by means of notching and tang bolts.

The original timber sway braces were unique to the Old PWD truss in form, fabric and function:

- The form of Old PWD truss sway braces was large sawn rectangular timbers whereas the form of the sway braces for all the other four truss types was a more slender T-section.
- The fabric of the Old PWD truss sway braces was timber whereas the fabric of the sway braces for all the other truss types was metal, generally wrought iron or sometimes steel.
- The function of the Old PWD truss sway braces was originally to provide lateral restraint to the top chords, which is why the connections were carefully detailed to ensure robustness and strength in both tension and compression. The function of the sway braces for the other four truss types was originally not to provide lateral restraint to the top chords, but only to prevent excessive sway of the trusses due to vibration under load, and this is why the other truss types originally had significantly more slender sway brace designs.

Existing Condition

None of the sway braces are original in form, fabric or function, but have been replaced with metal sway braces. All existing metal sway braces consist of welded angle sections and were given a condition rating of 3 or 4 in the most recent inspection, indicating serious corrosion.

Analysis of Modifications

The capacity of the current sway braces is only a small fraction of the capacity of the original timber sway braces. The existing metal sway braces are not symmetrical due to their "L" rather than "T" shape and do not reflect the original aesthetic or design intent and detract from the structural integrity and the heritage integrity of the trusses. The metal sway braces are of much more slender cross-section than the originals, but extend at a shallower angle, making them much longer than the original sway braces. This modification to the sway braces

[114] Source: left: Bridge general file 410.62, right: 0101 410 BC 0107 #1.

necessitated elongation of the primary cross girders to which they are connected. Some of the primary cross girders have been replaced with longer timber cross girders, but others have had metal extensions attached.

Figure 3-24: Photo of current metal sway braces and metal CG extensions.

(source: author 2017)

Approximately half of the long timber primary cross girders have been replaced with significantly longer timber primary cross girders, and the other half have been extended with metal channel sections bolted to the ends of the timber cross girders, sometimes with additional timber also added (see Figure 3-25). These extensions have very limited capacity due to the connection details as well as the slenderness of the sections when compared with the timber cross girders. The bolted connections of the metal sway braces to the timber top chords cause tension stresses perpendicular to the grain, exacerbating deterioration of timber at the ends of the top chords.

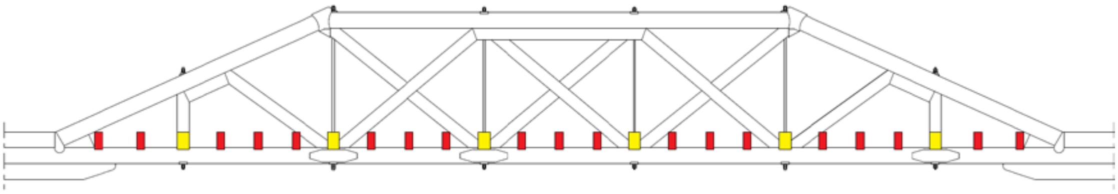
Figure 3-25: Photo of current metal sway braces and metal CG extensions.

(source: author 2017)

3.1.8 Truss span cross girders

The cross girders are shown in Figure 3-26, with primary cross girders (9" x 13" or 230 x 330 mm) highlighted in yellow and secondary cross girders (6" x 13" or 152 x 330 mm) highlighted in red.

Figure 3-26: Original 70' Old PWD design with cross girders highlighted.



(source: author)

Original Design

The original cross girders consisted of single solid timbers 13" (330 mm) deep of varying lengths. The long primary cross girders were the central four primary cross girders under the top chord supporting the sway braces and these were originally 24'6" (7468 mm) long. The short primary cross girders and the secondary cross girders were generally 19' (5790 mm) long. Two secondary cross girders in each span were slightly longer in order to provide a brace support to the ra[illegible]

All the secondary timber cross girders were originally notched 1" (25 mm) over the bottom chords to keep them in place in the lateral direction. The primary cross girders were notched into the bottom chord by 1" (25 mm). To further assist keeping the cross girders in place in the longitudinal direction, two rows of timber stringers were provided 6" (152 mm) deep notched into the sides of the cross girders so that the tops of the stringers were flush with the tops of the cross girders. These were located just inside of the line of the truss, and also supported the edge of the deck. This type of stringer is common to the Old PWD and McDonald truss, and performed a very different function to the stringers in later truss types (such as Allan, de Burgh and Dare trusses).

Existing Condition

None of the timbers in the primary or secondary cross girders are original fabric, but they are all still NSW hardwood. While the original timber used would have been sourced from old growth timbers, the existing timber cross girders are sourced from timbers available today. These timbers, sourced from younger trees, are significantly more susceptible to shrinkage than the original.

According to the most recent inspection (see Figure 3-28), all the cross girders (primary and secondary) have a condition rating of 3 or 4, indicating that the timber is in very poor condition.

Analysis of Modifications

Much of the original detailing has been lost. There is no notching of cross girders or bottom chords at connection locations, there are no stringers keeping cross girders in position and supporting the deck, the dimensions of the cross girders are not original in cross-section or in length. Part of the reason for this would be the excessive shrinkage of available timber making these original details ineffective. Another reason for these modifications is simply ease and cost of maintenance.

Originally the primary cross girders were located at panel points, kept in position by notching, and these determined the geometry of the truss. The fact that the primary cross girders are no longer adequately secured in position has contributed to the loss of geometry of the trusses as a whole.

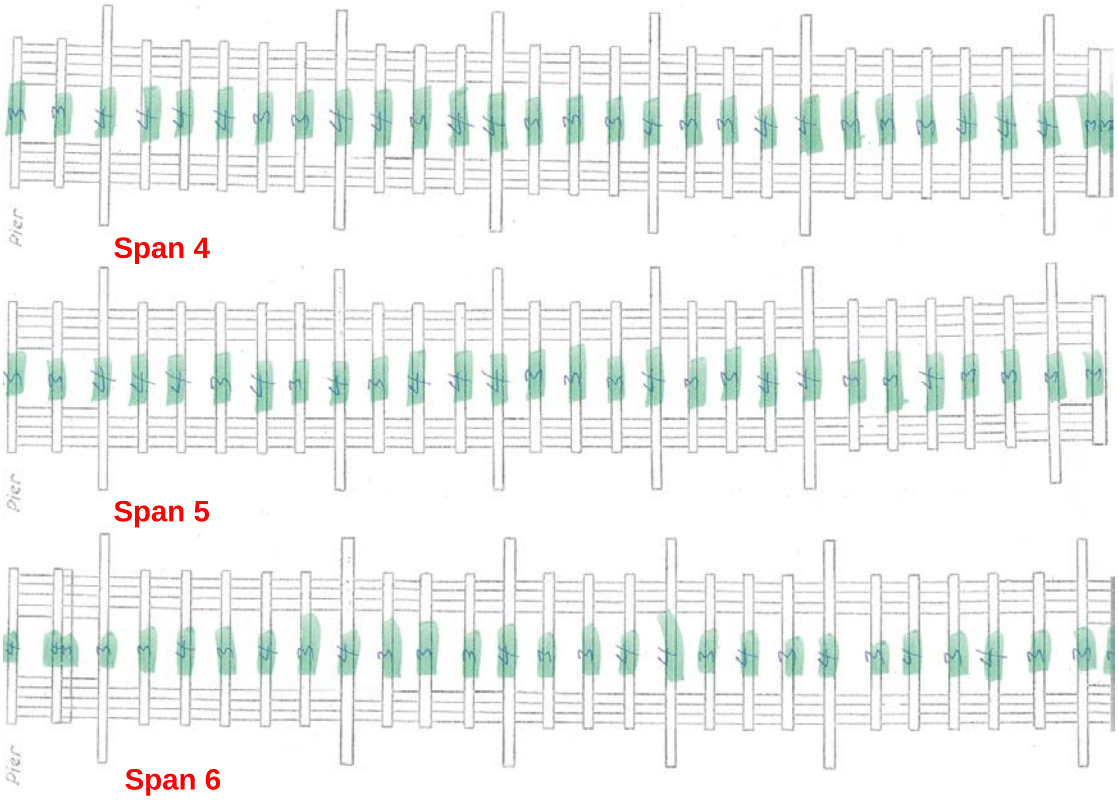
These modifications mean that the current cross girders do not reflect the original aesthetic or design intent and detract from the structural integrity and the heritage integrity of the trusses.

The original number of cross girders remains and the distinction between primary and secondary cross girders also remains in that the primary ones are larger than the secondary ones.

Figure 3-27: Photo of cross girders with no notching or stringers.

(source: author 2017)

Figure 3-28: 2016 inspection condition ratings for truss spans.



(source: Roads and Maritime)

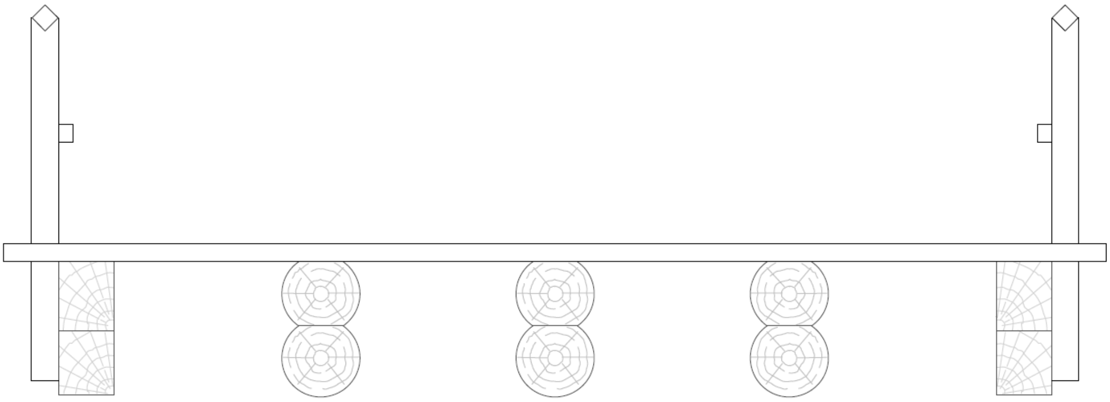
3.1.9 Approach spans

Original Design

Without the original drawings clearly detailing the approach spans, there is some speculation required to determine what the original configuration of the approach spans and substructure were at this bridge, especially with regard to span lengths. One of the original drawings which most closely represents what may have been constructed (Figure 2-33) indicates approach span lengths of 28'0", 40'0" and 40'0" (8.53 m, 12.19 m and 12.19 m). A sketch on the original drawings which may be original, or may have been added later (Figure 2-31) shows slightly different approach span lengths of 40'5", 40'0" and 29'8" (12.32 m, 12.19 m and 9.04 m). A sketch in the "Blue Book" which would be dated prior to 1930 (Figure 2-32) shows two span lengths of 40'5" and one of 29'8".

The original pier and abutment locations for the approach spans are therefore not certain. However, the general configuration of the approach spans can be determined with a high level of certainty because these details were standard details and remain somewhat intact at the bridge. There were originally three approach spans, and these approach spans consisted of round and sawn timber girders supported on round and sawn timber corbels at pier locations. The timber girders supported a timber deck and timber railings, with the configuration shown in Figure 3-29.

Figure 3-29: Original approach span configurations showing girders and corbels.

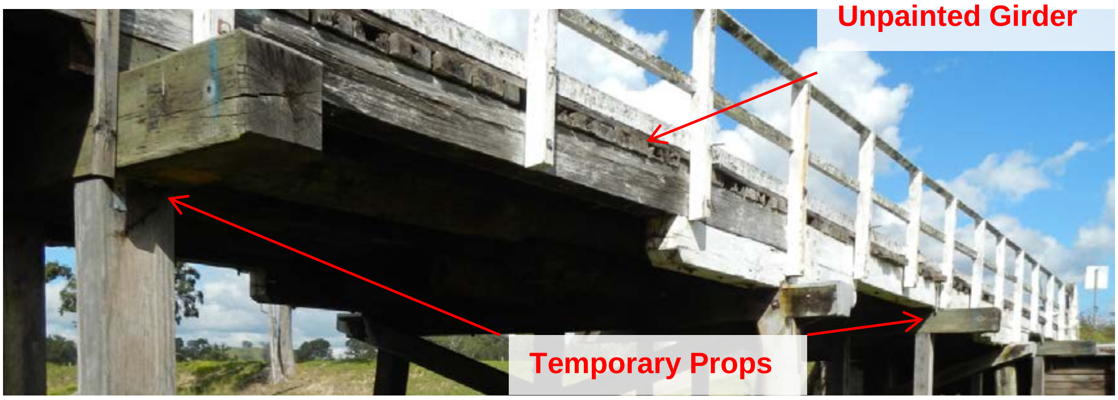


(source: author)

Existing Condition

The approach spans contain no original fabric, either of timber or metal. According to the most recent inspection in 2016, twelve of the fifteen timber girders are rated as condition state 4, and one as condition state 3 and two as condition state 2. Five of the ten corbels are rated as condition state 4, three as condition state 3 and two as condition state 2. This indicates that almost all the timber is very poor condition. Mid-span temporary supports have been installed (see Figure 3-30).

Figure 3-30: Photograph showing unpainted girder and temporary props.



(source: author 2017)

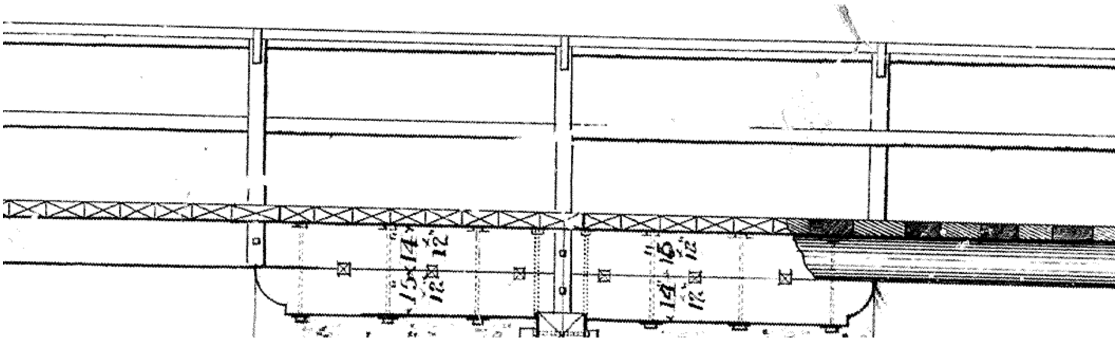
Analysis of Modifications

The current span lengths are 9.14, 12.19 and 12.19 m. The general configuration consisting of three central round timber girders and two outer sawn timber girders remains largely as original.

The detailing of the approach spans has been substantially modified as follows:

- The shapes of the corbels were originally carefully detailed to maximise strength and durability as well as to give some aesthetic distinction to the timber structures (see Figure 3-31). The corbels are now greatly simplified, with the original curved ends and vertical drip line replaced with a simple chamfer. Also, the timber shear keys originally used to connect the corbels more rigidly to the girders have been deleted (see Figure 3-32).

Figure 3-31: Original detailing of corbels on approach spans.

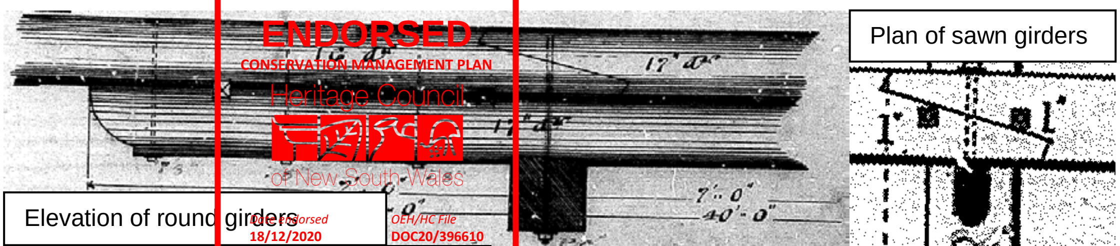


(source: 0101 410 BC 0107 #3)

Figure 3-32: Photograph showing current detailing of approach spans.

(source: author 2017)

Figure 3-33: Original scarf joint design for round and sawn girders.



(source: 0101 410 BC 0107 #3).

- The horizontal and vertical scarf joints which were originally used to connect the timber approach span girders have been replaced with simpler square ended butt joints. The original vertical scarf joint in the central round timber girders is shown on the left in Figure 3-33 above and the horizontal scarf joint in the outer sawn timber girders is on the right. These details were typical of approach spans on Old PWD and McDonald truss bridges.

- Part of the original connection of the timber posts for the railings is shown on the right hand side of Figure 3-33 above (a fuller discussion of the original timber railing details compared with the current details can be found under 3.2.10 below), and indicates that the horizontal bolt through the scarf joint also held the handrail in place. Because the scarf joint has been deleted, there is nothing for this bolt now to connect to, and so it has been deleted.
- Longitudinal timber sheeting and a timber kerb have been added to the top of the deck and so the timber railing is bolted to the kerb rather than to the timber girders at pier locations. At locations clear of the piers, the timber posts are connected to the girder and the kerb.
- Timber spacers have been added between the outer girders and the timber posts on the downstream side of the approach spans which further changes the aesthetic of the spans.
- The original iron spikes used to connect the single layer of transverse timber decking to the girders has been replaced with bolts which can be seen from below, and detract from the original aesthetic of clean round and sawn girders (Figure 3-34). In addition to the bolts in the girders, there are a very large number of bolts seen on the underside of the decking which is also not an original feature, but is due to the addition of longitudinal sheeting.
- One of the outer timber sawn girders has not been painted white (see Figure 3-30).

Figure 3-34: Photograph of bolts viewed beneath approach spans.

(source: Roads and Maritime)

3.1.10 Decking

Original Design

The original decking consisted of tarred 4” (100 mm) thick timber planking which was laid transversely on the three timber approach spans and diagonally on the three timber truss spans. Although scuppers were provided for drainage on the later four truss types, no scuppers were required on the Old PWD type timber truss bridges because they were designed without kerbs, and so water could freely drain off the bridge without any obstacles. The fact that the original designers even considered providing drainage for timber decks should alert us to the fact that leaky timber decks today are very different to the timber decks originally provided on timber truss bridges.

Although we do not have any original specifications for an Old PWD truss, we do have an original specification for a Dare truss, and photographic evidence indicates that similar specifications applied to all five types of timber truss bridges when it came to the treatment of the timber deck. Following are excerpts from an original specification for the construction a timber truss bridge:

> *Timber employed to be…. Tallow-wood, white mahogany, grey gum, red gum, grey box, blackbutt, or brush box, at option of Contractor, for the planking… All to be of approved quality, sound, straight, free from sapwood, large or loose knots, wanes, shakes, gum-veins, cores, or other defects; to have clean sharp arrises, and to be of the full dimensions shown or specified… Sawn timber to be absolutely free from heart, and to be so fixed that the surface which was farthest from the heart of the tree will be the outermost in the work other than planking, and uppermost in the planking… The flooring planks, which laid, to receive on the upper surface between kerbs one coat, composed of 7 parts coal tar, 4 parts of Stockholm tar, and 1 part of pitch, thoroughly melted together, and applied hot; to be well sprinkled with a layer of clean sharp sand and lime…. All tarring to be completed before painting is commenced, and no tar is to be applied during or immediately after wet weather, or while surface of timber is wet…. Floor to consist of 4-in. sawn planking, from 6 in. to 10 in. wide, laid transversely, as shown. All planks to run the entire width of bridge in one length; to be laid flush and close, and secured to girders and stringers by ⅜-in. square spikes, 7 in. long, two spikes at each intersection; heads of spikes to be drifted down ¼ in., and surface of the floor left smooth, all inequalities being adzed down…*[115]

The differences between the above specification and the Old PWD truss decks are only the lack of kerbs, the direction of the decking and the fact that the Old PWD used wider planks up 12 inches (304 mm) wide, whereas the later truss types had to use more narrow planks due availability.

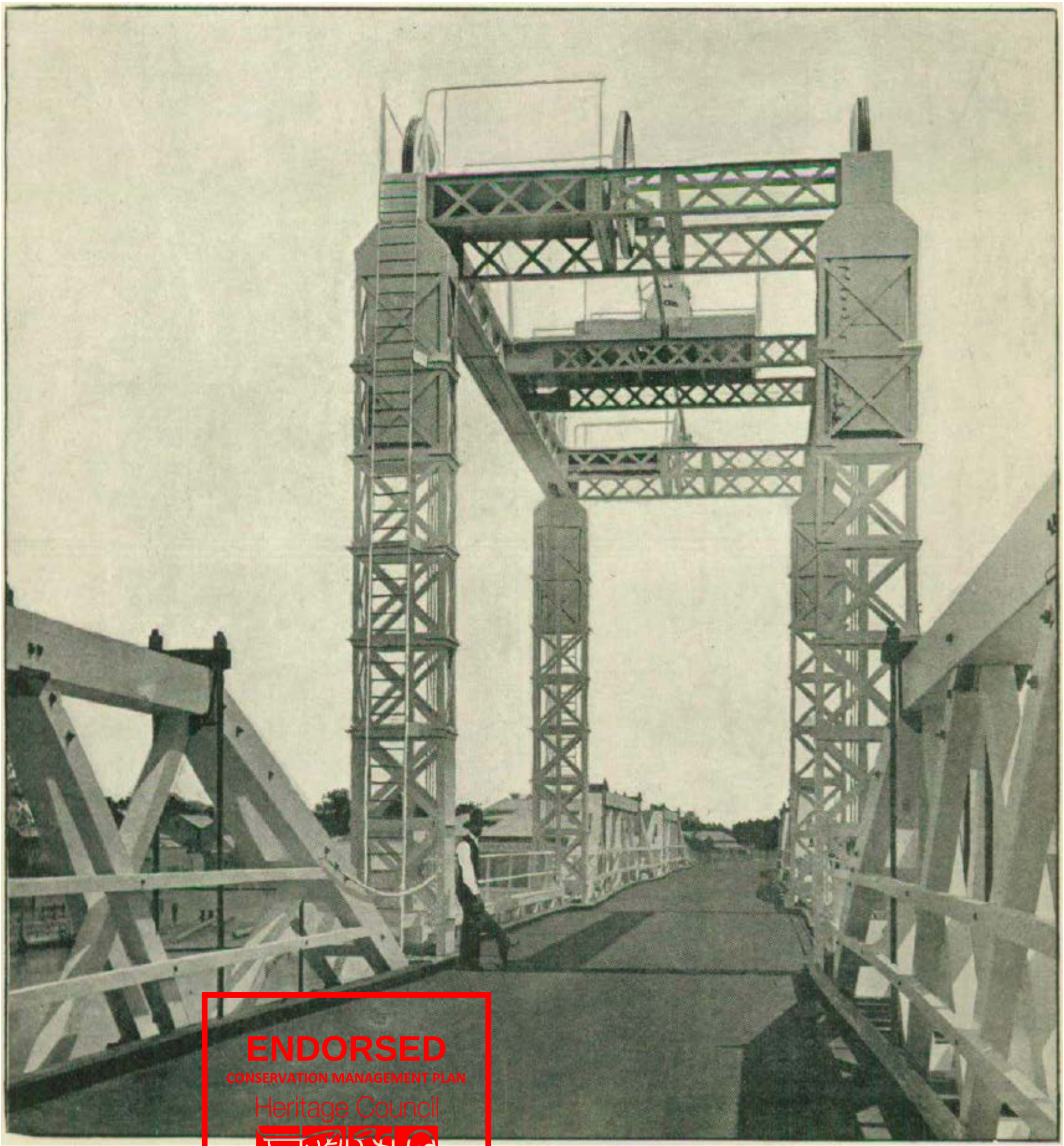
The primary function of the deck is to carry traffic. Originally a tarred surface was provided in order to minimise the slipperiness of the exposed timber deck so that vehicles and cattle could cross safely as well as to provide a protection against water to maximise the durability of the timber deck. Much care was taken to achieve a smooth safe deck surface. This means that the aesthetic of the original bridge was considerably less determined by the timber deck (which was smooth and dark and visually recessive) and considerably more focused on the truss with its white-painted timber.

Figure 3-35 gives an indication of the original aesthetic of timber decks on timber truss bridges. The photograph was taken in 1894 and shows a new McDonald truss bridge. The smoothness of the deck as well as the dark colour of the deck indicates that a similar

[115] Dept. Public Works, NSW Harbours, Roads and Bridges Branch, Contract for construction of a composite truss bridge over Wakool River, at Gee-Gee Crossing, Swan Hill to Deniliquin Road, Specification, 1928.

specification was used in 1894 as was used 35 years later when the specification mentioned above was written. The fact that these timber deck details were used with very little modification (the earlier two designs had flat decks with diagonal planks, whereas the later three designs had cambered decks with transverse planks and generous scuppers) by all five timber truss designers indicates that the details worked well at the time in which they were used. This is a testament to the quality of the timber which they were using, as the timber available today does not achieve the same results.

Figure 3-35: Original timber deck on timber truss bridge, Darling River at Wentworth in 1894.[116]



Existing Condition

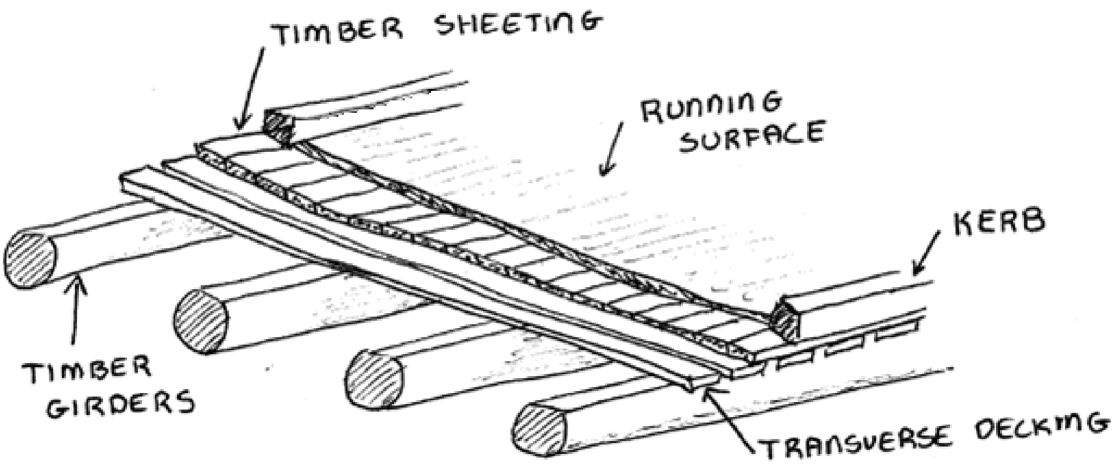
None of the deck is original fabric. According to the most recent inspection, all timber decking on all spans is rated as condition states 3 and 4, indicating that all timber is in very poor condition.

[116] Source: NSW Legislative Assembly: Report of the Dept. of Public Works for Year Ended 30 June, 1894.

Analysis of Modifications

The deck on the truss spans currently consists of spaced diagonal timber decking 100 mm thick with 50 mm thick longitudinal timber sheeting and timber kerbs on most spans. The deck on the approach spans currently consists of spaced transverse timber decking 100 mm thick with 50 mm thick longitudinal timber sheeting and timber kerbs. The longitudinal sheeting on all spans has been coated with a bituminous spray seal incorporating aggregate to provide a wearing surface.

Figure 3-36: Hand sketch showing typical decking terminology used today.



(source: author)

The current configuration does not reflect the original design intent on the truss spans or the approach spans either generally or in the particular details as outlined in the following.

- Originally the deck was completely flat and smooth with a black tar surface on top. The iron spikes which connected the decking to the girders and cross girders were hammered flush with the top of the timber and were covered with the tar thereby making them effectively invisible. The deck currently is significantly more textured, and somewhat overwhelms the aesthetic of the bridge with the strong longitudinal lines of the sheeting and the irregular spacing of the protruding bolt heads and joints in the sheeting when viewed from above.

Figure 3-37: Photograph showing current heavily textured timber deck.

(source: author 2017)

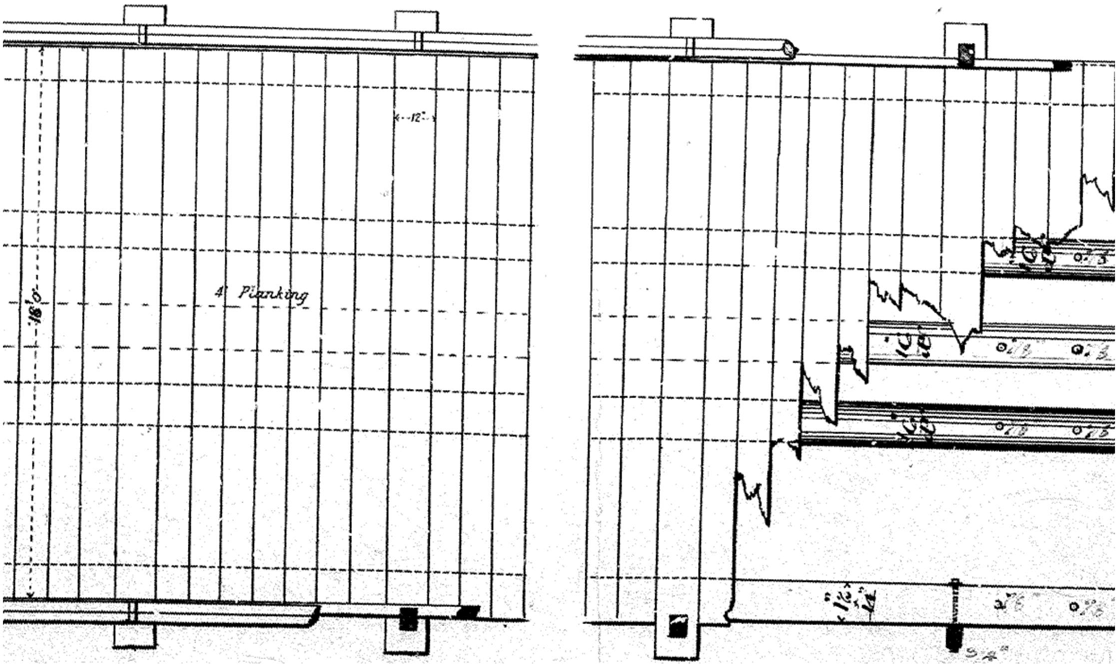
- Originally the deck was tightly spaced (allowing no light through) and smooth when viewed from beneath. All of the decking connections were hidden when viewed from beneath (iron spikes penetrated only partially into the girders and cross girders) so there were no deck bolts protruding through the approach span girders or the truss span cross girders. Currently the decking is spaced, allowing light through the deck, and a large number of bolts have been added in both the truss spans (Fig 3.46) and approach spans (Fig 3.42).

Figure 3-38: Photograph showing view of deck from beneath truss span.

(source: author 2017)

- One detail on the approach spans which was unique to approach spans of Old PWD trusses was the original detailing of extended deck planking at post locations. Originally, wider planks (12" or 304 mm wide) were provided at post locations and were extended approximately 12" (304 mm) beyond the rest of the planking to provide a robust connection for the timber posts supporting the railings without the need to introduce a kerb (see Figure 3-39 below). These deck plank extensions had 6" x 4" (152 x 100 mm) holes in them to accommodate posts of the same size, and a horizontal bolt was provided through the plank and post to keep the post secure and to prevent the deck from splitting. All of this original detailing has been lost with the introduction of kerbs to the approach span of the bridge.

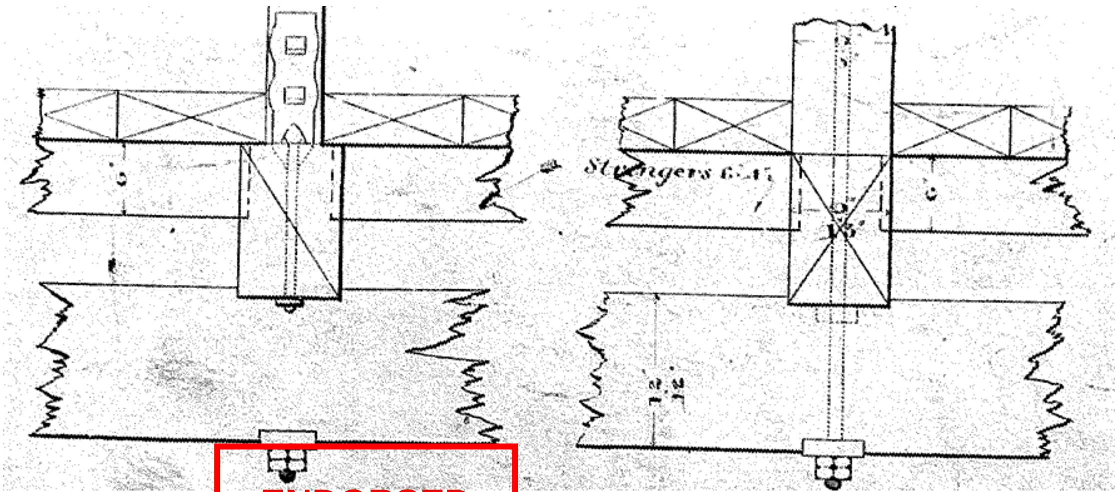
Figure 3-39: Original design plan of approach span deck.



(source: 0101 410 BC 0107 #3)

- As previously noted in Section 3.2.8, the detailing of the edge of the decking on the truss spans has also been substantially modified with the loss of the original stringers (sometimes called spiking planks) which were originally provided at the edge of the deck.

Figure 3-40: Original stringers and truss span deck in elevation.



(source: 0101 410 BC 0107 #1)

- Because of the introduction of gaps in the diagonal decking, and also due to the fact that the origi[illegible] been taken to give some aesthetic distinction to the timber bridge, the edge of the decking along the truss spans is a messy and jagged line (Figure 3-41).

Figure 3-41: Photograph showing edge of deck from on top of truss span.

(source: author 2017)

3.1.11 Railing

Original Design

The original timber railing had no real structural capacity and was not intended to be a traffic barrier for vehicles, but was intended to delineate the sides of the bridge for vehicles and to prevent horses, bullocks, sheep and cows (who were the most frequent bridge users) from falling off the bridge. When Monkerai Bridge first opened in 1882, the automobile had not been invented, and still by 1908 there were estimated to be only 1,000 motor cars in New South Wales (with 600 chauffeurs employed).[117] The roads were such that vehicles travelled much more slowly than they do today, and vehicles were much lighter than today. The first speeding fine handed down in Australia was in 1897, when George Innes of Sydney was fined ten shillings for travelling at 8 m/hr (13 km/hr).[118] Released in 1909, a Report of the Royal Commission for Improvement of the City of Sydney and its Suburbs did not include any strategies specifically geared towards the motor car because most people believed the car had no future beyond its function as a recreational toy.[119]

Existing Condition

None of the railing is original fabric. According to the most recent inspection, timber railings on all spans are rated as condition states 3 and 4, indicating that all timber is in very poor condition.

[117] Rosemary Broomham, *Vital Connections: a history of NSW roads from 1788*, Hale & Ironmonger in association with the Roads and Traffic Authority NSW: 2001, pp 100-102
[118] Bill Harrison, A History of the Department, an article for the DMT staff newsletter dated 30 April 1982, p 2.
[119] Rosemary Broomham*, Vital Connections: a history of NSW roads from 1788*, pp 103-104.

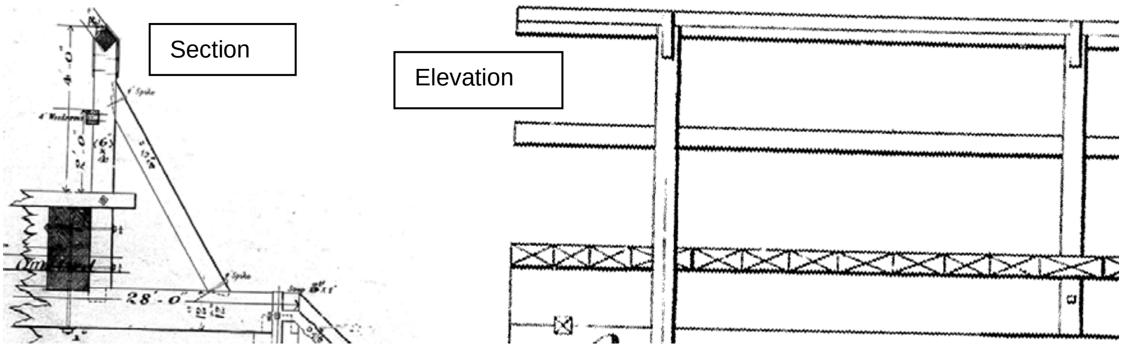
Analysis of Modifications

Some of the changes in detailing have already been described above including the modifications to the connections between the posts and the deck and between the posts and the girders as well as the introduction of new connections between the posts and the kerbs which have been added. These modifications have made the railing more similar to later timber railings used in Allan, de Burgh and Dare trusses, thereby blurring the distinguishing features between the different bridge types. Another example of this is the introduction of large end posts at Monkerai Bridge (although these are somewhat obscured now due to the bridge closure and the overgrown vegetation, so an older photograph is provided in Figure 3-42). The original design details are shown in Figure 3-43, and consist of a normal timber post with a timber brace connected directly to the abutment.

Figure 3-42: Photograph showing end posts which have been added.

(source: author 2012)

Figure 3-43: Original design detailing for end of timber railing.



(source: 0101 410 BC 0107 #3)

Some of the railings on the truss spans are broken (Figure 3-44) and others are missing (Figure 3-45).

Figure 3-44: Photograph showing broken railings on truss span.

(source: author 2017)

Figure 3-45: Photograph showing missing railings on truss span.

(source: author 2017)

3.1.12 Piers and abutments

Original Design

Without the original drawings clearly defining the pier and abutment configurations, there is some speculation required to determine the original configuration of the piers and abutments at this bridge. While it is probable that the piers and abutment of the truss spans are in their original locations, even the locations of the original approach span piers and abutment are uncertain.

Although there is a good early photograph of the top of the bridge, and a number of good (though admittedly faded) design drawings for the trusses, there are neither photographs nor drawings for the piers as constructed. The earliest photograph on file of the underside of the bridge was taken in the late 1960s, and by that time the bridge had already been in service for more than 85 years. The earliest record of the configuration of the piers is the 1938 sketches on file (see Figure 2-43).

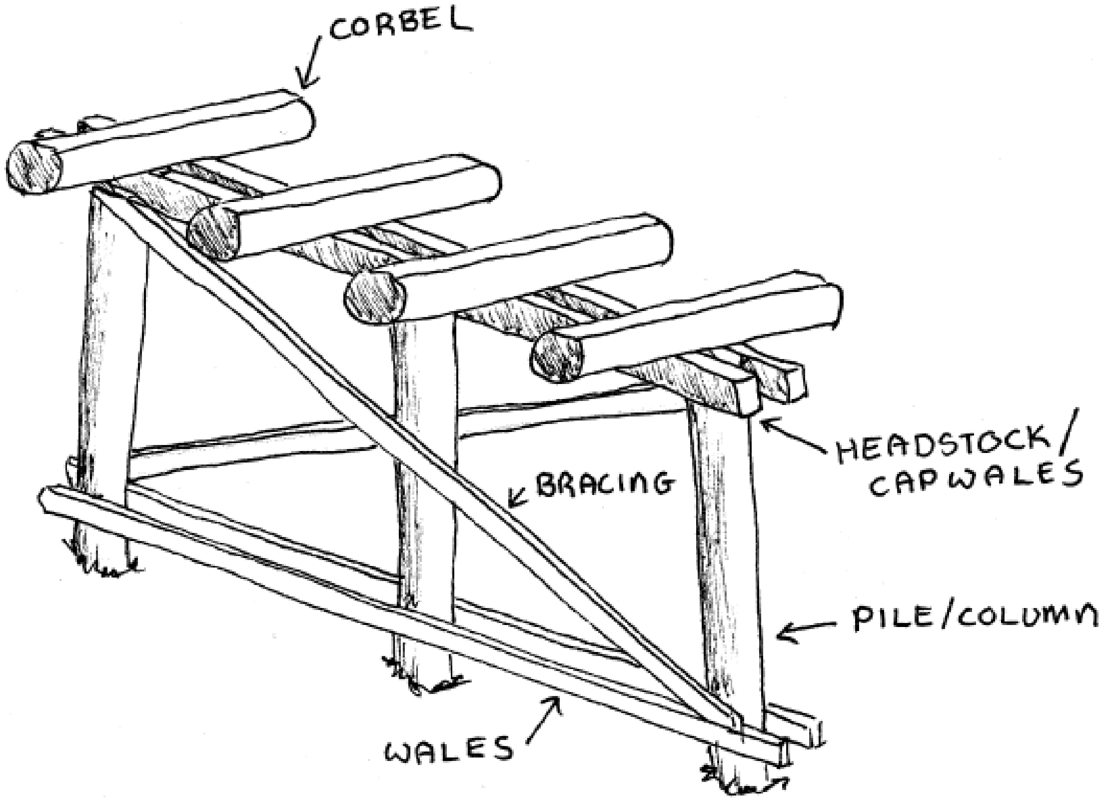
Driven timber piles in bridges, as a general rule, rot just below ground level within 30 to 40 years. These rotted timber piles are impossible to replace “like for like” or to restore to the original design. This is because, before a new timber pile can be driven, the remains of the buried old timber pile would have to be removed, and this is generally physically impossible. For this reason, timber piers and abutments tend to undergo numerous and significant modifications throughout their life.

There were originally three basic types of piers at Monkerai Bridge:

- Piers 1 & 2 are approach span piers
- Pier 3 is a transition pier
- Piers 4 & 5 are truss span piers

All timber piles on all piers would have originally extended to the top of the pier without splices. Piers 1 and 2 most likely originally consisted of three round driven timber piles with a single solid timber headstock at the top, a double timber wale at the bottom, and two single diagonal braces (one on each side of the pier in opposing directions) between the headstock and the wale.

Figure 3-46: Hand sketch showing typical timber trestle pier terminology.



(source: author)

Pier 3 most likely originally consisted of seven square driven timber piles with a single solid timber headstock at the top, a double timber wale at the bottom, and two single diagonal braces (one on each side of the pier in opposing directions) between the headstock and the wale.

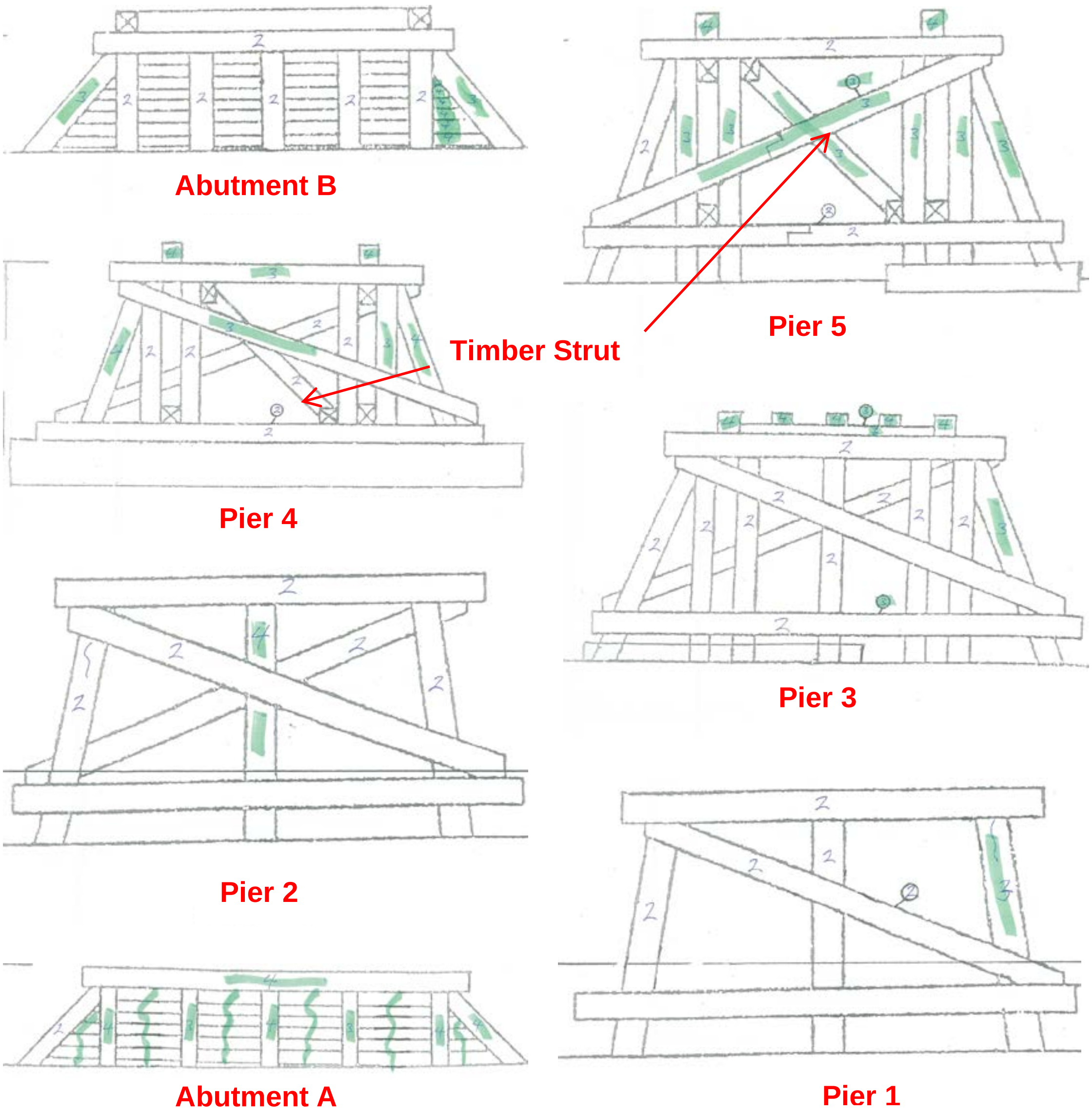
Piers 4 and 5 most likely originally consisted of six square driven timber piles with a single solid timber headstock at the top, a double timber wale at the bottom, and two single diagonal braces (one on each side of the pier in opposing directions) between the headstock and the wale. Piers 4 and 5 most likely also had a central diagonal timber strut (see Figure 3-47) to resist flood loads.

Both abutments most likely originally consisted of five round driven timber piles with a single solid timber headstock at the top and timber sheathing behind. Abutment most likely also had diagonal sloped round timber members to form the top of the wing walls and support wing wall sheathing. Each abutment would have had rock fill behind to eliminate forces due to earth pressure.

Existing Condition

The most recent inspection in 2016 is shown in Figure 3-47 below, indicating that the visible timber is in variable condition. None of the visible timber is original fabric (it is likely that remnants of the original timber piles remain buried deep in the ground). It is possible, though highly unlikely that some of the metal components on some of the piers and one abutment may be original fabric.

Figure 3-47: 2016 inspection condition ratings for substructure.



(source: Roads and Maritime)

Analysis of Modifications

All piers and abutments have been substantially modified, and these modifications have reduced the capacity of the structure to resist flood loads as well as impacting on the aesthetics of the bridge. Some of the piers have been completely reconstructed on reinforced concrete pile caps. Concrete has been introduced to other piers and abutments in the form of under-ground sleeves.

While the original design, consisting of un-spliced driven piles braced with timber above ground, had considerable capacity to resist flood loads, the introduction of various splices hidden underground has left the bridge at risk with regard to flood loads, detracting from the original design which was very carefully detailed due to the known risk of fast moving floods in the area. In addition to reducing the capacity to resist flood loads, the introduction of underground spliced connections strengthened with concrete sill beams or sleeves makes replacement of deteriorated timber even more difficult the next time, which has led to a large number of visually intrusive additional props and packing particularly at Piers 4 and 5 as shown in Figure 3-48 below.

Figure 3-48: Photograph of messy modifications to piers 4 & 5.

(source: Roads and Maritime)

Figure 3-49: Metal straps on Abutment A possibly original fabric.

(source: author 2017)

The other modification which has generally been made on timber trestle piers over the years is the deletion of the mortice and tenon joint which was originally provided at the pile to headstock connections. These connections were originally carefully detailed to provide some fixity and robustness in those connections, again to assist in resisting flood loads. Unfortunately, these mortice and tenon joints make replacing deteriorated timbers (whether they are the headstocks or the timber piles) difficult, and so this original carpentry detail is generally omitted in current bridges.

Therefore, although the current timber piers and abutments are still constructed from timber, they demonstrate very little of the original design detailing and leave the bridge at risk from flooding.

3.2 Summary of physical condition and heritage integrity

The bridge as a whole is in poor physical condition and has been substantially modified so that it also has poor heritage integrity, as it is not able to demonstrate the original design at the detailed level. However, it is still recognisable as an Old PWD type timber truss bridge, and still retains the form of most of the distinguishing features of the Old PWD design as outlined in Section 2.4.2.

The fact that the bridge is currently closed to traffic means that it cannot demonstrate the strength of the original design or the strength of the original NSW hardwoods with which it was constructed.

Elements	Condition	Integrity (ie: ability to demonstrate original design)
Truss span top chords and principals	Poor	Fair: Timber is not original fabric, sizes of timber not original and not consistent, additional splices introduced in two principals, trusses in general still recognisable as Old PWD.
Truss span bottom chords and butting blocks	Poor	Poor: Timber is not original fabric, configuration is not original, dimensions are not original, connections are not original, structural detailing has been lost, there are intrusive additions.
Truss span diagonals and props	Poor	Fair: Timber is not original fabric, sizes of timber not original and not consistent, introduction of timber and metal wedges means that one of the distinguishing features has been lost (since McDonald introduced metal wedges in his truss design).
Truss span metal components	Poor	Variable: Much of the metal is original fabric and so it can clearly demonstrate the original design. However, because the timber elements do not demonstrate the original design, the reasons for the design of the metal components is obscured and confused, thereby significantly reducing integrity. Some metal components have been removed altogether (bottom chord fish plates) and others have been modified to such an extent that they no longer demonstrate the original design (this is especially relevant for the tear drop shaped cast iron shoes).
Truss span sway braces	Poor	Poor: Metal is not original fabric and is not like the original fabric which was timber, configuration is not original, dimensions are not original, connections are not original, structural detailing has been lost, there are intrusive additions.
Truss span cross girders	Poor	Poor: Timber is not original fabric, configuration is not original, dimensions are not original, connections are not original, structural detailing has been lost, there are intrusive additions.
Approach spans	Poor	Poor: Timber is not original fabric, span lengths are not original, connections are not original, structural and aesthetic detailing has been lost, there are intrusive additions.
Decking	Poor	Poor: Timber is not original fabric, configuration is not original, detailing is not original, dimensions are not original, connections are not original, structural and aesthetic detailing has been lost, intrusive additions viewed from any angle.
Railing	Poor	Poor: Timber is not original fabric, detailing especially on approach spans and over piers is not original, detailing has been modified which blurs the distinctions between truss types.
Piers and abutments	Poor	Poor: Visible timber is not original fabric (some metal may possibly be original fabric), details underground have been modified and so the original strength and robustness is lost, original carpentry details have been lost, there are intrusive additions, and locations have been modified.
Visual setting and context	Poor	Poor: The bridge is fenced off, closed to traffic and the approaches are overgrown with vegetation, obstructing views.

4. Analysis of significance

4.1 Existing statement of significance

The NSW SHR statement of heritage significance for Monkerai Bridge currently reads,

> *The Monkerai Bridge is one of the most significant bridges in the NSW road network from a heritage perspective. It has been assessed previously as being of heritage significance at a National level (McMillan, Britton & Kell 1998)[120], although it is endorsed and managed by the RTA as being significant at a State level. While the Bridge is of aesthetic and social significance, its high level of heritage significance stems chiefly from it being of great historical and technical significance. The Bridge is the second oldest surviving timber truss bridge in the NSW road network, and is an exceptionally rare example of an Old PWD truss bridge. Old PWD truss bridges were the first in the five-stage development of timber truss bridges in NSW, and represent the genesis of this form of bridge construction. While the Bridge as a whole has been assessed as fulfilling the criteria for listing on the SHR, the various elements that comprise the Bridge are of varying levels of significance: abutments, piers, decking and hand railing are of moderate significance, of works the cross girders are of considerable significance and the truss spans are of exceptional significance.*[121]

This statement was derived from the draft CMP for Monkerai Bridge prepared in 2003.[122]

Considering the major changes that have taken place across the timber truss bridge population since then and new historical evidence as a result of further research, it is necessary to reassess whether this statement continues to adequately reflect the heritage significance of the bridge.

4.2 Comparative analysis

Of approximately 150 Old PWD type timber truss bridges constructed in NSW, only two remain today, these being Monkerai Bridge and the Brig O' Johnston over the Williams River at Clarence Town. Both of these were constructed towards the end of the Old PWD era (1858 to 1886) and so both were designed with details which were well standardised by that time. Both bridges were also designed with span lengths for which three central panels were detailed. Shorter 60' (18.29 m) spans were also standard designs having only two central panels, but none of these remain today.

The table below gives a comparison between the only two remaining Old PWD trusses. Although neither bridge is in good condition and neither has good heritage integrity, both are rare and both are representative of the standard design for the Old PWD truss for the relevant span length.

[120] MBK, *Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW*, 1998.
[121] SHR listing for Monkerai Bridge over Karuah River from Heritage Division website (accessed 31/05/17): http://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=5051379.
[122] RTA, *Conservation Management Plan, Monkerai Bridge*, Draft 25 June 2003.

Elements	Clarence Town	Monkerai
Year of opening	1880	1882
Type of truss	100’ (30.48 m) Old PWD truss	70’ (21.34 m) Old PWD truss
Description of original bridge	6 spans consisting of: • 45’ timber girder approach span • 100’ timber truss span • 100’ timber truss span • 45’ timber girder approach span • 45’ timber girder approach span • 40’ timber girder approach span The three cast iron piers supporting the truss spans and two timber trestle piers supporting the approach spans. A timber abutment at each end. Two approach spans had 1:30 grade.	6 spans consisting of: • 28’ timber girder approach span • 40’ timber girder approach span • 40’ timber girder approach span • 70’ timber truss span • 70’ timber truss span • 70’ timber truss span Five timber trestle piers having three different configurations for truss span, transition span and approach span. A timber abutment at each end. Original grade was flat on all spans.
Distinguishing features between 100’ and 70’ original designs	Timbers are larger and longer. The 100’ Old PWD truss has two tension rods at each panel point. The 100’ Old PWD truss has the double top chord extending up to half a metre beyond double diagonals. The 100’ Old PWD truss has a space between flitches of double diagonals. Fish plates are more rectangular and have ten bolts through each plate.	Timbers are smaller and shorter. The 70’ Old PWD truss has a single tension rod at each panel point. The 70’ Old PWD truss has the double top chord stopping at the intersection with double diagonals. The 70’ Old PWD truss has no space between flitches of double diagonals. Fish plates are less rectangular and have six bolts through each plate.
Fabric condition	Generally poor – supported by Bailey.	Generally poor – closed to traffic.
Heritage integrity	Generally poor • Original geometry lost throughout • Single solid top chords replaced with smaller shorter laminates • Some cast iron shoes replaced with poor metal substitutes • Timber sway braces replaced with poor metal substitutes • Fish plates lost • Bottom chord laminate layout lost • Abutments moved, timber piers modified, cast iron piers original • Approach span timber girders replaced with steel, corbels lost • Deck significantly modified	Generally poor • Original geometry lost throughout • Single solid top chords remain, but some other members spliced • Some cast iron shoes broken, modified or replaced with different • Timber sway braces replaced with poor metal substitutes • Fish plates lost • Bottom chord laminate layout lost • Abutments and piers modified and additional propping provided • Approach span timber girders modified in details throughout • Deck significantly modified
Heritage listings	LEP, Section 170 Register, SHR	Section 170 Register, SHR

4.3 Assessment of significance

4.3.1 Criterion A – Historical

An item is important in the course, or pattern, of NSW's cultural or natural history.

Guidelines for INCLUSION

- *shows evidence of a significant human activity*
- *is associated with a significant activity or historical phase*
- *maintains or shows the continuity of a historical process or activity*

Guidelines for EXCLUSION

- *has incidental or unsubstantiated connections with historically important activities or processes*
- *provides evidence of activities or processes that are of dubious historical importance*
- *has been so altered that it can no longer provide evidence of a particular association*

Monkerai Bridge is the second-oldest surviving timber truss road bridge in New South Wales.

The excellence in design of the Old PWD truss is historically significant as the first of five stages of timber truss road bridge design in New South Wales, proving and popularising the timber truss as the preferred form of bridge construction for medium span bridges in New South Wales until the early 1900s. Monkerai Bridge is one example of the Old PWD design which performed well beyond the expectations of the original designer, with the average life of the Old PWD being 54 years, 26 bridges remaining in service beyond 80 years, and two still remaining today after 135 years. The bridge is therefore able to demonstrate the State historical theme of "Technology".

Monkerai Bridge provided an essential link for the reliable transport, particularly of timber and dairy produce, between Dungog and Gloucester. Also of importance was the need for speedier and more regular communication between the Hunter River and Manning districts, as well as the needs of the locals of Monkerai to safely cross the river in all weather. It is historically significant through its association with the expansion of the New South Wales road network, and the contribution of that road system to settlement, development and economic activity throughout New South Wales. The bridge is therefore able to demonstrate the State historical theme of "Transport".

The historical context for the original design and construction of Monkerai Bridge was plentiful New South Wales hardwoods, particularly that large and long old growth timbers were readily available and vast numbers of bridges were being built, but budgets were tight and skilled workmen were few. As noted by Dare, the hardwood timbers used were second to none in Australia, and indeed compared favourably both for strength and durability, with any timbers in the world.

Monkerai Bridge is associated with a historical phase when quality hardwood timber was available and was widely used in public works locally as well as being exported all around the world. The original design demonstrates a time long gone when quality hardwood timber was plentifully available, and the later history of the bridge demonstrates that the resource is no longer available.

Monkerai Bridge therefore meets this criterion at a State level.

4.3.2 Criterion B – Associative

An item has strong or special association with the life or works of a person, or group of persons, of importance in NSW's cultural or natural history.

Guidelines for INCLUSION

- *shows evidence of a significant human occupation*
- *is associated with a significant event, person, or group of persons*

Guidelines for EXCLUSION

- *has incidental or unsubstantiated connections with historically important people or events*
- *provides evidence of people or events that are of dubious historical importance*
- *has been so altered that it can no longer provide evidence of a particular association*

As an Old PWD truss, Monkerai Bridge has strong associations with William Christopher Bennett, the designer of this truss type. Bennett was recognised as one of the ablest officers in the government service, and held the position of Commissioner and Chief Engineer to the Roads Department of the New South Wales Department of Public Works from 1862 until 1889. The total length of main roads built by Bennett and his department was nearly 16,000 km along with 64 km of bridges, many of them the largest in the southern hemisphere, and some remaining today.

The bridge as a whole is in poor physical condition and has been substantially modified so that it is not able to demonstrate the original design at the detailed level. However, it is still recognisable as an Old PWD type timber truss bridge, and still retains the form of most of the distinguishing features of the Old PWD design. There remains sufficient evidence of Bennett's original design details of the trusses in original drawings, early photographs and the remaining original fabric still to provide evidence that Monkerai Bridge was the work of one of Australia's ablest engineers. Monkerai Bridge therefore meets this criterion at a State level.

4.3.3 Criterion C – Aesthetic / Technical

An item is important in demonstrating aesthetic characteristics and/or a high degree of creative or technical achievement in NSW.

Guidelines for INCLUSION

- *shows or is associated with, creative or technical innovation or achievement*
- *is the inspiration for a creative or technical innovation or achievement*
- *is aesthetically distinctive*
- *has landmark qualities*
- *exemplifies a particular taste, style or technology*

Guidelines for EXCLUSION

- *is not a major work by an important designer or artist*
- *has lost its design or technical integrity*
- *its positive visual or sensory appeal or landmark and scenic qualities have been more than temporarily degraded*
- *has only a loose association with a creative or technical achievement*

Monkerai Bridge fits neatly into the rural landscape, being aesthetically pleasing in scale, proportion and materials used. As a timber truss bridge with its original black and white colour scheme, the trusses in particular are aesthetically distinctive and have landmark qualities.

However, it is the innovative and practical engineering which is particularly notable in the Old PWD trusses, and this engineering excellence is seen, not primarily in the general shape of the trusses, but in their details, the flow of forces, the connections and the structural rigidity. These details have been largely lost due to modifications, but many details can be restored. The design of this truss type was also the inspiration for further technical innovation in the four following truss types. Monkerai Bridge therefore meets this criterion at a State level.

4.3.4 Criterion D – Social

An item has strong or special association with a particular community or cultural group in NSW for social, cultural or spiritual reasons.

Guidelines for INCLUSION

- *is important for its associations with an identifiable group*
- *is important to a community's sense of place*

Guidelines for EXCLUSION

- *is only important to the community for amenity reasons*
- *is retained only in preference to a proposed alternative*

Monkerai Bridge is of some significance to the people of Monkerai, but primarily as a transport link. For the last thirteen years, the bridge has been closed to vehicular traffic, and no longer performs any function for the local community other than carriage of pedestrians. Locals understandably point out that the closed bridge has hindered development in the valley, disadvantaged landholders on both sides, and created operational and logistical difficulties for businesses in the district.

The fact that Monkerai Bridge is listed on the Register of National Trust indicates that the local community are not the only stakeholders for this bridge. Engineers, historians and National Trust members (for example) provide some social significance, but not sufficient to meet the criterion.

Monkerai Bridge does not currently meet this criterion at the State or local level.

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4.3.5 Criterion E – Scientific / Archaeological

An item has potential to yield information that will contribute to an understanding of NSW's cultural or natural history.

Guidelines for INCLUSION

- *has the potential to yield new or further substantial scientific and/or archaeological information*
- *is an important benchmark or reference site or type*
- *provides evidence of past human cultures that is unavailable elsewhere*

Guidelines for EXCLUSION

- *the knowledge gained would be irrelevant to research on science, human history or culture*
- *has little archaeological or research potential*
- *only contains information that is readily available from other resources or archaeological sites*

One Aboriginal archaeological site (isolated artefact) has been identified just outside the curtilage, assessed as displaying low scientific significance. Two areas of potential archaeological deposit (PAD) have been identified outside the curtilage but within the general setting, and these were assessed as displaying moderate archaeological potential.

It is likely that there may be archaeological remains of the original timber piles for the piers and abutments buried deep underground, which may also include some original metal driving shoes. These archaeological remains of Monkerai Bridge have the potential to yield further information about timber pile driving techniques and timber pile detailing in the early 1880s.

The bridge contains some metal elements which are probably original fabric, including cast iron shoes and wrought iron washer plates on the truss spans and possibly some wrought iron straps on an abutment. These provide a future opportunity for materials testing and analysis to yield further information about the properties of iron used in bridges in the early 1880s.

Monkerai Bridge therefore meets this criterion at a State level.

4.3.6 Criterion F – Rarity

An item possesses uncommon, rare or endangered aspects of NSW's cultural or natural history.

Guidelines for INCLUSION

- *provides evidence of a defunct custom, way of life or process*
- *demonstrates a process, custom or other human activity that is in danger of being lost*
- *shows unusually accurate evidence of a significant human activity*
- *is the only example of its type*
- *demonstrates designs or techniques of exceptional interest*
- *shows rare evidence of a significant human activity important to a community*

Guidelines for EXCLUSION

- *is not rare*
- *is numerous but under threat*

Monkerai Bridge is exceptionally rare as the only remaining example of a 70' Old PWD truss, and as one of only two remaining examples of Old PWD trusses out of approximately 150 built.

Monkerai Bridge therefore meets this criterion at a State level.

4.3.7 Criterion G – Representativeness

An item is important in demonstrating the principal characteristics of a class of NSW's cultural or natural places; or cultural or natural environments.

Guidelines for INCLUSION

- *is a fine example of its type*
- *has the principal characteristics of an important class or group of items*
- *has attributes typical of a particular way of life, philosophy, custom, significant process, design, technique or activity*
- *is a significant variation to a class of items*
- *is part of a group which collectively illustrates a representative type*
- *is outstanding because of its setting, condition or size*
- *is outstanding because of its integrity or the esteem in which it is held*

Guidelines for EXCLUSION

- *is a poor example of its type*
- *does not include or has lost the range of characteristics of a type*
- *does not represent well the characteristics that make up a significant variation of a type.*

The bridge as a whole is in poor physical condition and has been substantially modified so that it is not able to demonstrate the original design at the detailed level. However, it is still recognisable as an Old PWD type timber truss bridge, and as one of only two remaining Old PWD timber truss bridges, Monkerai Bridge is representative of the this type of bridge having retained to some extent the form of most of the distinguishing features of the Old PWD design. There remains sufficient evidence of the original design details of the trusses in original drawings, early photographs and the remaining original fabric still to provide evidence of the construction and design techniques used in this earliest form of timber truss bridge design widely used in New South Wales.

Monkerai Bridge therefore meets this criterion at a State level.

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4.4 Revised statement of significance

Monkerai Bridge is of State significance as the second-oldest surviving timber truss road bridge in New South Wales. It is rare and representative as the only remaining example of a 70’ Old PWD truss and as one of only two remaining examples of Old PWD trusses of approximately 150 built.

The excellence in design of the Old PWD truss is historically significant as the first of five stages of timber truss road bridge design in New South Wales, proving and popularising the timber truss as the preferred form of bridge construction for medium span bridges in New South Wales. It is historically significant through its association with the expansion of the State road network, and the contribution of that road system to settlement, development and economic activity.

As an Old PWD truss, Monkerai Bridge has strong associations with William Christopher Bennett, the designer of this truss type. Bennett was recognised as one of the ablest officers in the government service, and held the position of Commissioner and Chief Engineer to the Roads Department of the New South Wales Department of Public Works from 1862 until 1889.

The historical context for the original design and construction of Monkerai Bridge was plentiful New South Wales hardwoods, particularly that large and long old growth timbers were readily available and vast numbers of bridges were being built, but budgets were tight and skilled workmen were few. The New South Wales hardwood timbers used were second to none in Australia, and indeed compared favourably, both for strength and durability, with any timbers in the world. The design is an example of innovative and practical engineering in a time when large and long old growth timbers were readily available and vast numbers of bridges were being built with a tight budget.

Monkerai Bridge fits neatly into the rural landscape, being aesthetically pleasing in scale, proportion and materials used. As a timber truss bridge with its original black and white colour scheme, the trusses in particular are aesthetically distinctive and have landmark qualities. There is some scientific / archaeological potential in the original fabric of the bridge and its setting.

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4.5 Grading of significant components

The OCMP sets out the methodology and approach taken here to grading of significant components. The table below provides a summary of the grading of significant components.

Table 4-1: Summary of the grading of significant components

Elements	Significance	Summary of justification for significance
Truss span top chords and principals	Exceptional (State)	Although the timber top chords and principals do not contain original fabric, are much deteriorated, and some details have been modified, the original design can still be inferred.
Bottom chords and butting blocks	Intrusive	Modifications to these elements are so substantial that these elements are now damaging to the item's heritage significance, causing structural deficiencies and undermining interpretation.
Diagonals and props	High (State)	Alterations detract from aesthetics and only partially reflect the original design intent and original strength and robustness.
Truss span metal	High (State)	Some original fabric is of exceptional significance, but other metal components are modified or missing completely.
Truss span sway braces	Intrusive	Modifications to these elements are so substantial that these elements are now damaging to the item's heritage significance, causing structural deficiencies and undermining interpretation.
Truss span cross girders	Little	Details common, and do not directly contribute to significance, have been substantially altered, undermining interpretation.
Approach spans	Little	Details common, and do not directly contribute to significance, have been substantially altered, difficult to interpret.
Decking	Intrusive	Modifications to these elements are so substantial that these elements are now damaging to the item's heritage significance, causing structural deficiencies and undermining interpretation.
Railing	Little	Details very common, and do not directly contribute to significance, have been substantially altered, difficult to interpret.
Piers and abutments	Little	Details very common, and do not directly contribute to significance, have been substantially altered and weakened.
Visual setting and context	Moderate	The visual setting and context has been modified over the decades, but still contributes to overall significance.

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5. Constraints and opportunities

As operational infrastructure, timber truss bridges function as part of the State's road network. Transport for NSW must ensure that the bridge is able to function appropriately. The bridge must also comply with statutory heritage constraints to ensure that its significance is conserved. In order to formulate appropriate conservation policies for the bridge and its environs, the requirements that will have an impact upon the future management of the bridge have been investigated and are summarised below.

5.1 Constraints and opportunities arising from significance

The following statements are not conclusions or recommendations but, rather, observations relevant to the circumstances of the site and matters that require consideration and resolution.

5.1.1 Criterion A – Historical

The historical context of this bridge is the availability of high quality (strong and durable) New South Wales hardwood. The significance of the truss is so closely related to the New South Wales hardwoods, these being the very reason for the design and vast use of this form of construction, that its conservation should prioritise the continued the use of NSW hardwood timbers. The availability of high-quality hardwood timber required for heritage timber truss bridges is a substantial concern. It is an increasingly scarce resource, and is valuable as part of our natural heritage, as well as for its usefulness in carrying heavy vehicles over heritage timber truss bridges.

Although at least two pieces of heart-free sap-free bridge timber should be able to be recovered from a single log, in practice (on average) less than a single piece per log meets the requirements for use in most heritage timber truss bridges. This increases the responsibility of those caring for the bridge to ensure that all works maximise the durability of timber in order to minimise the need to cut down old growth forests, which are part of the valuable natural heritage of this country.

Careful consideration should also be given to replacing timber with modern materials where the heritage significance of the fabric of the particular element is little or moderate, and where the introduction of modern materials would not substantially affect the heritage significance of the bridge as a whole. Relevant statutory approvals would need to be obtained.

Timber truss bridges have strong associations with the expansion of the road network and economic activity throughout NSW so the conservation of this bridge should retain its use as a vital part of the NSW road infrastructure, which may necessitate some elements being strengthening.

5.1.2 Criterion B – Associative

As an Old PWD truss, Monkerai Bridge has strong associations with William Christopher Bennett and has the opportunity to demonstrate the engineered design details of one of Australia's ablest engineers. Although the bridge as a whole is in poor physical condition and has been substantially modified to the extent that it is not currently able to demonstrate the original design at the detailed level, there remains sufficient evidence of the original design in the original drawings of the 70' Old PWD trusses and early photographs to allow restoration and reconstruction within the bounds of Articles 19 and 20 of the *Burra Charter*. The conservation of this bridge should seek to apply engineering excellence so as not to obscure the work of one of Australia's ablest engineers.

Because the original design made use of and relied upon old growth ironbark timber not available today, it is not possible to completely restore all of the original details completely in form, fabric and function. The excessive shrinkage and swelling of the younger hardwoods (less than 200 years old) that are available today mean that the original design, which worked for the older hardwoods, does not work today, so that trusses quickly become loose and sag, warp and fail. This does not demonstrate the strength of the original design or materials, and it does not allow accurate interpretation of the work of one of Australia's ablest engineers. Consideration must therefore be given to making necessary modifications to demonstrate the old design in the current context.

5.1.3 Criterion C – Aesthetic / Technical

As a timber truss bridge with its original black and white colour scheme, Monkerai Bridge is aesthetically distinctive and has some landmark qualities. There are opportunities to improve the views of the bridge by regular removal of excessive vegetation growth in the area.

However, it is the innovative and practical engineering which is particularly notable in the Old PWD trusses, and this engineering excellence is seen, not primarily in the general shape of the trusses, but in their details, the flow of forces, the connections and the structural rigidity. These details have been largely lost due to modifications, but there is opportunity to pursue restoration and reconstruction within the bounds of Articles 19 and 20 of the *Burra Charter*.

Article 22.1 of the *Burra Charter* states that, "New work such as additions or other changes to the place may be acceptable where it respects and does not distort or obscure the cultural significance of the place, or detract from its interpretation and appreciation." The design of this truss type was the inspiration for further technical innovation in the four following truss types. The conservation of this bridge, therefore, should not obscure the culturally significant original details, and should not obscure the differences between the Old PWD truss and the later four truss types.

5.1.4 Criterion D – Social

The bridge is currently not well esteemed by the local community primarily because its load limits and subsequent closure have hindered development in the valley, disadvantaged landholders on both sides, and created operational and logistical difficulties for businesses in the district.

The best way to conserve a heritage structure is to ensure that the local community continues to value it. A bridge that looks like it is the result of Band-Aid solutions or poor workmanship, left to deteriorate until traffic restrictions are put in place to carry out repairs is less likely to be valued by the community. A community is more likely to value a bridge if it has an element of beauty or elegance to it. It is also more likely to value a structure if convenience is maximised and inconvenience minimised. Community sentiment can be assisted by education through interpretation, but if the bridge does not safely and efficiently perform its primary intended function as a transport link across the river, then the social significance is substantially diminished.

Article 3.2 of the Burra Charter states that, "Changes to a place should not distort the physical or other evidence it provides, nor be based on conjecture." Similarly, the ICOMOS Principles for Historic Timber Structures emphasise the importance of authenticity and load-bearing function. Therefore, any new works required that might be required for strength or safety should be able to be interpreted as such, and the original design intent should not be obscured in the process.

Any conservation works on the bridge should aim to increase its social significance by community focused design. A community focused design will include, but not be limited to, the following:

- Elegance in Design: The bridge, and any additions to it, should be in keeping with the elegance and simplicity of the original, with any additions designed to be visually recessive;
- Road Safety: The Bridge should be safe for vehicles and for pedestrians where appropriate. This may require sensitively upgraded barrier rails, alignments and approach treatments;
- Transparency in Design: Design should enable the inquisitive to determine the original details, fabric and form where possible by not obscuring this by changes and additions;
- Durability in Design: The design should be detailed to maximise service life so that community impact of traffic diversions due to bridge closures is minimised;
- Strength for Modern Vehicles: The bridge should be strengthened to carry today's vehicles so that inconvenient load restrictions are minimised, and community benefit maximised;
- Interpretation: Information on the bridge and its history should be made readily available, and where appropriate, included in the vicinity of the bridge.

5.1.5 Criterion E – Scientific / Archaeological

The presence of original metal fabric at Monkerai Bridge provides some research potential. If original fabric needs to be removed from the bridge due to deterioration, then the fabric should be examined (eg, metallurgical examination) and recorded and samples retained for future research.

There is archaeological potential both within the curtilage (in the form of original piles) and outside the curtilage (potential archaeological deposits from Aboriginal activities). Any archaeological resources or collections of artefacts and records should be protected and conserved.

5.1.6 Criterion F – Rarity

Monkerai Bridge is the only remaining example of a 70' Old PWD truss and one of only two remaining examples of Old PWD trusses of any span so the trusses should be conserved.

5.1.7 Criterion G – Representativeness

The bridge as a whole is in poor physical condition and has been substantially modified so that it is not able to demonstrate the original design of the Old PWD truss at the detailed level. The representativeness could be enhanced by restoring original details which have been modified, as there remains sufficient evidence of the original design to provide the opportunity for restoration and reconstruction of the trusses within the bounds of Articles 19 and 20 of the *Burra Charter*.

5.2 Constraints and opportunities from current listings

5.2.1 Summary and assessment of current listings

The *Environmental Planning & Assessment Act 1979* gives local governments the power to protect places of heritage significance through local environmental plans (LEP), which include provisions for development controls and identify any incentives that council may offer. Monkerai Bridge is listed on the schedule of heritage items in the Great Lakes Local Environmental Plan.[123]

[123] Great Lakes LEP 2017 http://www.legislation.nsw.gov.au/#/view/EPI/2014/176/sch5 (accessed 05/06/17)

Section 170 of the *Heritage Act 1977* requires government agencies to identify, conserve and manage heritage assets owned, occupied or managed by that agency. It also requires that the government agencies keep a register of heritage items. The progress of agencies in preparing registers and managing their heritage assets is monitored by the Heritage Council. In accordance with the Heritage Act, Roads and Maritime has established a Heritage and Conservation Register to record all heritage items in its ownership or under their control, including Monkerai Bridge.

The NSW Heritage Council developed seven criteria gazetted under section 4A (3) of the *Heritage Act 1977* to help guide decisions about whether an item is of State heritage significance. Monkerai Bridge has been assessed against these criteria above and six of the seven criteria are satisfied at a State level. Section 33 (3) of the Heritage Act 1977 states that, in general, two or more criteria need to be satisfied for the Heritage Council to recommend State listing. Monkerai Bridge clearly meets the criteria for listing and so is rightly listed on the State Heritage Register.

Places of National heritage significance, Commonwealth Heritage Places or World Heritage are protected under the *Environmental Protection and Biodiversity Conservation Act 1999*. This Act allows places which are thought to be of outstanding heritage value to the Nation to be listed, managed and protected. Section 324D of the *Environmental Protection and Biodiversity Conservation Act 1999* states: “A place has a National Heritage value if and only if the place meets one of the criteria prescribed by the regulations for the purposes of this section.” Clause 10.01A(2) of the *Environmental Protection and Biodiversity Conservation Regulations 2000* give the criteria:

The National Heritage criteria for a place are any or all of the following:

a) the place has outstanding heritage value to the nation because of the place’s importance in the course, or pattern, of Australia’s natural or cultural history;

b) the place has outstanding heritage value to the nation because of the place’s possession of uncommon, rare or endangered aspects of Australia’s natural or cultural history;

c) the place has outstanding heritage value to the nation because of the place’s potential to yield information that will contribute to an understanding of Australia’s natural or cultural history;

d) the place has outstanding heritage value to the nation because of the place’s importance in demonstrating the principal characteristics of:

(i) a class of Australia’s natural or cultural places; or

(ii) a class of Australia’s natural or cultural environments;

e) the place has outstanding heritage value to the nation because of the place’s importance in exhibiting particular aesthetic characteristics valued by a community or cultural group;

f) the place has outstanding heritage value to the nation because of the place’s importance in demonstrating a high degree of creative or technical achievement at a particular period;

g) the place has outstanding heritage value to the nation because of the place’s strong or special association with a particular community or cultural group for social, cultural or spiritual reasons;

h) the place has outstanding heritage value to the nation because of the place’s special association with the life or works of a person, or group of persons, of importance in

Australia's natural or cultural history;

i) the place has outstanding heritage value to the nation because of the place's importance as part of indigenous tradition.

Monkerai Bridge is not an item of World Heritage and does not meet the criteria for inclusion on the Commonwealth heritage list. However, it has been assessed previously as being of heritage significance at a National level.[124] The 1998 assessment was not based on the above criteria and was never endorsed, but it does highlight that the bridge may meet some of the National Heritage criteria, particularly criteria (b) and (f) which emphasise the technical achievement and rarity.

A summary of the statutory and non-statutory lists is provided in the table below, with whether or not Monkerai Bridge meets the criteria for listing and whether or not the bridge is currently listed:

Register / List	Brief Explanation	Meets Criteria	Listed
World Heritage List	Properties forming part of the cultural and natural heritage which the World Heritage Committee considers as having outstanding value.	No	No
Commonwealth Heritage List	A list of natural, indigenous and historic heritage places owned or controlled by the Australian Government.	No	No
National Heritage List	Places of outstanding heritage significance to Australia, including natural, historic and indigenous places of outstanding value.	Yes	No
State Heritage Register	A list of places and objects of particular importance to the people of New South Wales, including items in both private and public ownership.	Yes	Yes
Section 170 Heritage Register	Lists Roads and Maritime's assets which have been identified as having State or local heritage significance	Yes	Yes
LEP Heritage Schedule	List with maps in principal legal document for controlling development and guiding Council's planning decisions.	Yes	Yes
Register of National Trust	Non-Statutory register identifies historic places of national and local significance through expert committees.	Yes	Yes

5.2.2 State Heritage Register Listing and Heritage Council of NSW Approvals

The SHR is a list of heritage items of particular importance to the people of New South Wales. It includes items and places of State heritage significance endorsed by the Heritage Council of NSW and the Minister. The SHR is established under Section 22 of the *Heritage Act 1977,* and pursuant to Section 57(1) of the Act, the approval of the Heritage Council of NSW is required for any proposed development within the site including subdivision, works to the grounds or structures or disturbance of archaeological 'relics'.

[124] MBK, *Study of Relative Heritage Significance of All Timber Truss Road Bridges in NSW*, 1998, p 90.

The *Heritage Act 1977* requires minimum standards of maintenance and repair for items on the SHR to ensure heritage significance is retained. These standards are set out in the *Heritage Regulation 2012*.

5.2.3 Exemptions from *Heritage Act 1977* approval

Section 57(2) of *the Heritage Act 1977* provides for a number of exemptions to Section 57(1) approval requirements, meaning that a Section 60 approval does not need to be sought. Routine maintenance and minor repairs consistent with standard exemptions would not require Heritage Council approval before commencing. Other works including minor structural alteration, major refurbishment, safety and operational upgrades, would require approval of the Heritage Council of NSW, either as a Section 57 exemption or a Section 60 application. Details of typical works are provided in Appendix A.

5.2.4 Archaeology

The *Heritage Act 1977* affords automatic statutory protection to 'relics'. The Act defines a 'relic' as:

> *"any deposit, artefact, object or material evidence that:*
>
> *a) relates to the settlement of the area that comprises New South Wales, not being Aboriginal settlement and*
>
> *b) is of State or local heritage significance."*

Any excavation or works to a site listed on the SHR likely to disturb relics would require an approval to carry out a Section 57(1) activity, except in accordance with a gazetted exemption.

In the event that substantial or unexpected archaeological relics are encountered within the curtilage, the Department of Premier and Cabinet should be notified, pursuant to Section 146 of the *Heritage Act 1977*. Further assessment, and possibly further approval, may be required at the discretion of the Department of Premier and Cabinet. The Transport for NSW archaeological protocols cover the process to be followed in such circumstances.

5.2.5 Aboriginal heritage

Legislative protection of Aboriginal objects and places is provided by the National Parks and Wildlife Act 1974 (NPW Act). It is an offence under the NPW Act to undertake any action that causes harm to an Aboriginal object or Aboriginal Place without the express permission of the Chief Executive of Heritage NSW. Part 6 of the NPW Act provides statutory protection for all Aboriginal objects (comprising any deposit, object or material evidence of the Aboriginal occupation of NSW) and for 'Aboriginal places' (areas of special cultural significance to the Aboriginal community that have been gazetted as such under Section 84 of the NPW Act). All Aboriginal objects are afforded automatic statutory protection in NSW, as are Aboriginal Places. It is an offence to undertake any action that causes harm to Aboriginal objects and Aboriginal Places in New South Wales without prior consent. The NPW Act defines harm as any act or omission that destroys, damages or defaces the object or place.

5.2.6 State owned Heritage Management Principles

The State Owned Heritage Management Principles were issued in 2004 under Section 170A (2) of the *Heritage Act 1977*. The Heritage Asset Management Guidelines were issued in 2004 under Section 170A (3). Items particularly relevant to this bridge are tabulated below.

Table 5-1: Summary of relevant provisions of the *State-owned Heritage Management Principles*

Citation	Quotation	Implication
3. Lead by Example	State agencies should lead by example by adopting appropriate heritage management strategies, processes and practices. The public sector should set the standard for the community in the management of heritage assets.	Conservation should be of the highest standard.
4. Conservation Outcomes	Heritage assets should be conserved to retain their heritage significance to the greatest extent feasible. State agencies should aim to conserve assets for operational purposes or to adaptively reuse assets in preference to alteration or demolition.	Significance should be conserved to the greatest extent feasible.
8. Maintenance of Heritage Assets	Heritage assets are to be maintained in a manner which retains heritage significance, with the objective of preventing deterioration and avoiding the need for expensive “catch-up” maintenance and major repairs.	The bridge should not be allowed to fall into disrepair.
9. Alterations	Alterations should be planned and executed to minimise negative impacts on heritage significance, and appropriate mitigating measures should be identified.	Any alterations should minimise heritage impacts.

Table 5-2: Summary of relevant provisions of the *Heritage Asset Management Guidelines*

Citation	Quotation	Implication
2.2 Adoption of the *Burra Charter* (p 17)	State agencies should adopt the *Burra Charter* for the making of management decisions for heritage assets. In accordance with the *Burra Charter*, management decisions should also consider other factors affecting the future of a heritage asset such as the owner’s needs, resources, external constraints and its physical condition.	Management decisions need to be made in accordance with the *Burra Charter*.
3.6 Interpretation of Heritage Significance (p 20)	The heritage significance of many heritage assets is not readily apparent and should be explained by interpretation, in accordance with the document, Heritage Interpretation Guidelines. Interpretation should enhance understanding and enjoyment, and be culturally appropriate.	A Heritage interpretation strategy should be prepared for the bridge.
3.27 Contemporary & Design Excellence of New Additions (p 25)	New additions to heritage assets, including new constructions in the vicinity of heritage significance, should be identifiable as having been designed and built in the present. New additions are to include contemporary design and materials as appropriate, as well as being sympathetic to identified heritage values. Designs should be executed with appropriate materials and finishes.	Any new work on the bridge must exhibit engineering excellence and be sympathetic to heritage value.
3.29 Removal of Intrusive Elements (p 25)	Wherever practical, elements identified as being “intrusive” to the heritage significance of a heritage asset should be removed.	Intrusive elements should be removed.

5.2.7 State Agency S170 Heritage and Conservation Registers

Section 170 of the *Heritage Act 1977* requires that all Government departments or agencies maintain a Heritage and Conservation Register, which includes all assets owned or in the care and control of the relevant department or agency that are of State or local heritage significance. Under Section 170A of the *Act*, 14 days prior notice to the Heritage Council of NSW is required in the event that Transport for NSW:

a) removes any item from its register under Section 170; or

b) transfers ownership of any item entered in its register; or

c) ceases to occupy or demolishes any place, building or work entered in its register.

5.2.8 Local Environmental Plan and Local Council Approvals

The NSW Environmental Planning and Assessment Act 1979 establishes Local Environmental Plans (LEPs) as the relevant local planning instrument in any council-controlled area in NSW. LEP listing does not restrict or prohibit any development by Transport for NSW, as Clause 5.12 generally states:

"Infrastructure development and use of existing buildings of the Crown

1) This Plan does not restrict or prohibit, or enable the restriction or prohibition of, the carrying out of any development, by or on behalf of a public authority, that is permitted to be carried out with or without development consent, or that is exempt development, under State Environmental Planning Policy (Infrastructure) 2007.

2) This Plan does not restrict or prohibit, or enable the restriction or prohibition of, the use of existing buildings of the Crown by the Crown."

The State Environmental Planning Policy (Infrastructure) 2007, Clause 94 (1) states that,

"Development for the purpose of a road or road infrastructure facilities may be carried out by or on behalf of a public authority *without consent on any land."*

5.2.9 Total Asset Management

The NSW Government has established various requirements and standards for the delivery of government services and infrastructure in NSW. The Government's 'Strategic Management Framework' summarises and defines the various processes which NSW Government agencies are required to use in order to plan activities and services, to allocate resources and to report on performance. Total Asset Management (TAM) is a part of the framework. With constant reference to whole-of-government planning, the agency's Corporate Plan, and its Service Delivery Strategy, the TAM approach requires asset managers to assess what assets are needed to support successful service delivery. It then calls for detailed plans for the management of those assets which are to be acquired, maintained or disposed of. The Total Asset Management approach provides an overarching context for decisions in relation to this bridge.

5.3 Constraints and opportunities from operational requirements

As part of its road network management responsibilities, Roads and Maritime manages almost six thousand bridges and major culverts. The Roads and Maritime 2020 Strategic Plan (August 2015) outlines strategic priorities, and conforming to these strategic priorities is a requirement for all Roads and Maritime activities, including maintaining timber truss bridges as operational assets.

- The Roads and Maritime Strategic Priorities are:
- Making safety paramount
- Delivering our infrastructure program
- Meeting customer and community needs
- An organisation that delivers
- Enhancing economic and social outcomes.

Making safety paramount

The *Work Health and Safety Act 2011* and the *Work Health and S*afety Regulation 2011 are administered by SafeWork NSW, and aim to secure the health and safety of workers and workplaces, which includes construction or maintenance people working on bridges.

Work Health and Safety (WHS) legislation in New South Wales emphasises the need for employers to provide a safe working environment for their employees or contractors. The safety risks of maintenance at Monkerai Bridge are significant, including working at heights, working near traffic, working near overhead powerlines, working over water, working with hazardous materials (timber preservatives, termite treatments and possibly lead paint) and manual handling. In order to meet legislative safety requirements, sometimes traditional methods of construction and repair are not feasible, and so changes must be introduced to facilitate safe maintenance of the bridge.

In the NAASRA (National Association of Australian State Road Authorities) Highway Bridge Design Specification of 1965, there are design requirements for roadway railings on bridges, for footway railings on bridges, and for “crash resisting railings” on bridges. Even in 1965, barriers were only designed to actually resist impact loads from vehicles on, “bridge structures carrying traffic over busy thoroughfares”, otherwise design loads were approximately 2 kN/m. In 1992, the AUSTROADS Bridge Design Code came into effect, and barrier loads increased to 90 kN. In 2004 a new Australian Standard for Bridge Design, AS 5100 introduced a design load up to 500 kN to resist heavy vehicles. In the 2017 revision, that design load has further increased to 600 kN.

Timber rails do not have any ability to prevent a vehicle from falling off the bridge. On the contrary, timber rails are a spearing risk to errant vehicles and their passengers. There have been a number of instances of vehicles driving off the sides of timber truss bridges in NSW, with some fatalities. Photographs below are typical of what happens when a car loses control at a timber truss bridge.

The likelihood of accidents on timber bridges is accentuated by the slippery timber decks. It is therefore likely that a traffic barrier and new deck will be required at Monkerai Bridge in the future.

Figure 5-1: Vehicle recovery after crash on timber truss bridge.

(source: Roads and Maritime)

Delivering our infrastructure program

In 2012, Roads and Maritime and the NSW Heritage Council agreed upon a strategy for the future management of the forty-eight timber truss bridges then controlled by Roads and Maritime. This strategy recognised Roads and Maritime's role as the custodian of the heritage significance of the population of timber bridges as well as its responsibility to provide safe road infrastructure at reasonable cost in an environment of increasing vehicle size and growing traffic volumes.

In accordance with the endorsed Strategy, a number of timber truss bridges, including Monkerai Bridge, are to be conserved by having them upgraded to carry live loads equivalent to current heavy vehicle requirements by the application of several proven upgrade procedures.[125]

Addressing the State's deficient rural bridges is a key priority for NSW Government investment. A new and dedicated infrastructure development program was set up in 2012 to fund the necessary upgrade of the network. Two high priority strategic program investment areas were identified, the first being Higher Mass Limit bridge restrictions and the second, heritage timber truss bridges.[126]

This initiative, called Bridges for the Bush, is a commitment from the NSW Government to improve road freight productivity by replacing or upgrading bridges at key locations in regional NSW. The NSW road network is critical to the movement of freight in Australia. Half the nation's road freight and three quarters of all interstate road freight journeys are on NSW roads. With the road freight task predicted to nearly double by 2030, significant investment in the NSW road network is required to meet the demand for increased access of larger, safer and heavier freight vehicles.[127]

Tranche 2 of the Bridges for the Bush program was developed in 2016 and is consistent with the Roads and Maritime Timber Truss Bridge Conservation Strategy 2012. Monkerai Bridge over the Karuah River is one of five timber truss bridges included in Tranche 2 for upgrading in a heritage sympathetic manner to reduce future maintenance costs and improve safety against failure.[128]

The business case for the program which includes Monkerai Bridge is given as follows:

> *Timber truss bridge upgrades are necessary to improve structural safety of these bridges. These bridges are opened for General Mass Limit vehicles and Livestock vehicles carrying HML loads. Originally these timber truss bridges have been designed to carry 16 – 17 tonne traction engines and now they carry 42.5 tonne semi-trailers and some instances 45.5 tonne semi-trailers with lower safety margins. Further maintenance of these bridges requires high quality large timber sections which are difficult to obtain. Maintenance costs of these bridges are 50 – 60 times of similar concrete bridges. The proposed upgrades generally incorporate steel elements to minimise the risk of sudden failure. Monkerai, Colemans and New Buildings bridges are of State heritage significance and require NSW Heritage Councils approval for any upgrade. RMS generally uses strengthening methods that have already approved by the NSW Heritage Council. Therefore the risk of not getting approval for strengthening of these bridges could be rated as low.*[129]

[125] Roads and Maritime, *Timber Truss Bridge Conservation Strategy, Submissions Report and Revised Conservation Strategy*, August 2012, ISBN 978-1-922194-17-6, p 44.
[126] http://www.rms.nsw.gov.au/projects/freight-regional/bridges-for-bush.html (accessed 06/06/17)
[127] http://www.rms.nsw.gov.au/documents/projects/freight-regional/bridges-for-the-bush-mr-fact-sheet.pdf
[128] The other four timber truss bridges included are Briner Bridge over Upper Coldstream River, Beryl Bridge over Wialdra Creek, Colemans Bridge over Leycester Creek and New Buildings Bridge over Towamba River.
[129] Transport for NSW, Bridges for the Bush Tranche 2, Strategic Program Business Case, V3, Jan 2016.

The sudden failure of one span of Monkerai Bridge in June 2000 (despite considerable repair work carried out in the years leading up to the failure) as described in Section 2.6.3 highlights the reality of the structural risks at the bridge, and the need to incorporate some strengthening measures to minimise the risk both to the bridge users, and to the heritage item itself.

Meeting customer and community needs

The bridge is currently not well esteemed by the local community primarily because its load limits and subsequent closure have hindered development in the valley, disadvantaged landholders on both sides, and created operational and logistical difficulties for businesses in the district.

The primary needs of the local community for the crossing are for pedestrians (especially for daily access for school), cyclists and passenger vehicles (particularly tourists but also locals), the ambulance and fire engine in case of emergencies, buses (particularly the school bus) as well as the farmer's requirements for truck and dog combination vehicles and semi-trailers.[130] These community needs are not dissimilar to the needs of the community in the late 1800s which caused the bridge to be constructed in the first place. Particularly, the bridge was originally constructed to meet the needs of children to be able to safely cross the river to attend school and the needs of local and regional farmers to be able to efficiently transport their goods. It is therefore very appropriate that the bridge be repaired in such a way to continue this use for which it was built.

One of the non-original uses of the bridge is to support the local tourism industry. While this was not the use for which the bridge was originally constructed, it is a very suitable use for a heritage timber truss bridge because the bridge itself can be appreciated as a tourism destination.

There is an unfortunate history in New South Wales of building new concrete bridges next to existing timber truss bridges, and then demolishing the timber bridge when it becomes too hard to maintain. Efforts have been made in the past to find adaptive reuse for such bridges. In 1990, a single span of the unique bowstring timber truss over the Lachlan River at Cowra was reconstructed in an adjacent riverside park as a landmark of engineering heritage.[131] Although this project was originally heralded as a great success, within ten years, the reconstructed bridge had been so damaged by termites that it had to be demolished due to safety concerns. A bridge that had lasted almost a century under traffic including heavy loads did not last a decade without traffic.

Another adaptive reuse that has been tried is using a bridge to carry utilities. This was the case for de Burgh's bridge over the Lane Cove River. Built in 1900, it was the longest span timber truss built. A new concrete bridge was constructed for traffic in 1967, and ownership of the bridge was transferred to the Sydney Water Board because the bridge was being used to carry a water main.[132] The water main was decommissioned and the bridge burned down in a bushfire in 1994. Timber truss bridges on the road network have sometimes been damaged by fires (Monkerai Bridge has suffered fire damage in the past), but never destroyed because the fire is quickly extinguished. If the bridge had still been in use then it is unlikely it would have been destroyed.

There is often an idea that timber bridges could be adaptively reused to take pedestrians and cyclists. Although this may be suitable for other bridge types, the timber decking typical of

130 Roads and Maritime, memo dated 2 September 2004 regarding Monkerai Bridge Closure.
131 D.J. Fraser, *Cowra Bridge – Preservation of a Unique Structure*, Sixth National Conference on Engineering Heritage 1992, Hobart 5 – 7 October 1992, p 1.
132 R. Mackay, Conservation and Industrial Archaeology: Recent Work by the National Trust (NSW), *Australian Historical Archaeology*, Vol 4, 1986, p 15.

timber truss bridges causes hazards for cyclists and pedestrians.[133] Again, this has been attempted unsuccessfully a number of times, the worst example being an Allan truss in Glebe (Figure 5.2).[134]

Timber bridges need to be regularly inspected and maintained to protect against rot and termite attack, and pedestrian bridges do not receive sufficient use or funding, which means that such bridges deteriorate very quickly. In an ideal world, perhaps funding would be made available, but experience has shown that even with the best of intentions from all parties, this does not happen.

Figure 5-2: Johnston's Creek Bridge, failed pedestrian bridge at Glebe.

(source: J. McPhail, 2005)

Since experience has shown that these structures are very rarely successfully preserved by removing vehicular traffic and adaptive reuse, it is imperative that Monkerai Bridge be reopened and remains open to traffic. This will necessitate new work to ensure that the bridge is strong enough for the heavy vehicles which will use the route in the future, it may require upgrades to the deck and rails to provide adequate safety and slip resistance, and it may require modifications to the approach spans and substructures in order to mitigate against flood risks, minimise bridge closures and also in order to maximise the sustainability of the timber so it is available for the truss.

An organisation that delivers

Roads and Maritime have invested heavily into understanding timber truss bridges in the modern context so that a representative population can be conserved into the future. With almost 160 years of experience and over 400 timber truss bridges constructed, operated and maintained, there is a wealth of corporate knowledge within Roads and Maritime which cannot be found elsewhere.

[133] For example, *Sydney Morning Herald* article on 14 July 2013, "Bridge fall highlights maintenance crisis".
[134] J. McPhail, *Timber/Concrete Composite Module, Testing and Performance*, Australian Small Bridges Conference, October 2005, p 6.

Bridge rehabilitation generally, and in particular rehabilitation design for timber bridges, was recognised as an area to be strengthened in the Strategic Directions paper for Roads and Maritime's Technical Capability in 2008. As a result of this perceived skills shortage, sponsorships were offered to Roads and Maritime employees to undertake a Master of Engineering under Professor Keith Crews, a recognised leader in the area of timber structures, as well as a Master of Heritage Conservation to better understand the interrelationship between engineering and heritage. Furthermore, Roads and Maritime have been instrumental in the development of new Australian Standards on the design and rehabilitation of timber bridges, working with experts from industry and academia as well as other road authorities in other States and countries to ensure that the structural behaviour, risks and performance of timber bridges are accurately understood. This corporate knowledge and new research have been used to develop proven method for conserving timber truss bridges as part of the operational road network of New South Wales.

Enhancing economic and social outcomes.

An intangible economic benefit of the timber truss bridges is their heritage value. An important benefit of repairing and reopening Monkerai Bridge to traffic is that it enhances its heritage value.

Constraints and opportunities from condition and integrity

Elements	Constraints	Opportunities
Truss span top chords and principals	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement. Increasingly difficult to obtain timber.	Condition and integrity improved by replacing with new hardwood timbers of original dimensions and detailing.
Bottom chords and butting blocks	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement. Original design not sufficiently strong for current loads and cannot be constructed today due to WHS. Current configuration less strong than original and intrusive to significance.	Condition and integrity improved by replacing with new hardwood timbers of original dimensions and detailing in all visible locations (minor hidden modifications due to WHS). Strength improved by properly designed new work in line with Burra Charter principals for new work.
Diagonals and props	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement.	Condition and integrity improved by replacing with new hardwood timbers of original dimensions and detailing.
Truss span metal	Some metal components are original fabric but condition is poor. Some metal components are original fabric but have been irreversibly modified to accommodate bottom chord modifications. Some metal components are not original fabric or original design and condition is poor. Some metal components have been lost. Original cast iron is susceptible to brittle fracture. Original top chord shoes problematic due to shrinkage properties of currently available timber.	Condition and integrity improved by replacing with new metal components of original dimensions and detailing, making use of ductile cast iron where applicable, and introducing minor modifications (e.g. upsize tension rods) where necessary for current loads and to accommodate current shrinkage properties. Opportunity to preserve original fabric removed from the bridge for future research into 1880s metals.

Elements	Constraints	Opportunities
Truss span sway braces	Original form, fabric and function have been lost. Original detailing cannot be effectively reinstated due to shrinkage properties of currently available timber. Modifications to sway braces have also necessitated modifications to primary cross girders. Current configuration is less strong than original and intrusive, current configuration and detailing is also damaging to top chord timber.	Condition and integrity improved by replacing with new sway braces designed to perform original function detailed with similar form to original. Care of top chord timbers which are increasingly difficult to obtain can be assisted by careful detailing of sway braces to avoid damaging stresses on top chord timbers.
Truss span cross girders	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement. Original detailing of primary cross girders cannot be effectively reinstated due to shrinkage properties of currently available timber and excessive bridge closures required to maintain timber to original detailing. Timber primary cross girders cannot accommodate a complying traffic barrier.	Condition and integrity of secondary cross girders improved by replacing with new hardwood timbers of original dimensions and detailing. Condition and integrity of primary cross girders improved by replacing with new cross girders of original dimensions but different material which does not shrink and can accommodate a traffic barrier.
Approach spans	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement. Original design not sufficiently strong for current loads. Original detailing of approach spans cannot be effectively reinstated due to excessive bridge closures required to maintain timber. Approach spans cannot accommodate a complying traffic barrier as they have insufficient strength in their members and connections to resist the loads.	Approach spans have little significance and if they were reconstructed exactly to their original design, they would still only have moderate significance. There is therefore very limited opportunity to enhance the cultural significance in the approach spans.
Decking	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement. Original design not sufficiently strong for current loads. Original detailing cannot be effectively reinstated due to shrinkage properties of currently available timber and WHS hazards associated with original materials (tar).	Decking is currently intrusive but if it were reconstructed exactly to its original design, it would still only have moderate significance. There is therefore very limited opportunity to enhance the cultural significance in the decking, other than to reduce its intrusiveness by replacing with a new form of timber deck which performs the original function with similar fabric.
Railing	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement. Railing does not meet minimum safety requirements for heavy or light vehicles, cyclists or pedestrians.	Railings have little significance and if they were reconstructed exactly to their original design, they would still only have little significance. There is therefore very limited opportunity to enhance the cultural significance in the railings. There is, however, opportunity to enhance the social significance of the bridge by improving the safety of the bridge by replacing with new traffic barriers.

Elements	Constraints	Opportunities
Piers and abutments	Timber is not original fabric and cannot be returned to original fabric. Termite and rot necessitates replacement. Original detailing cannot be effectively reinstated due to impossibility of driving new timber piles where old timber piles have been driving previously. Current configuration is less strong than original and leaves the bridge at risk of washing away in flood.	Piers and abutments have little significance and if they were reconstructed exactly to their original design, they would still only have moderate significance. There is therefore very limited opportunity to enhance the cultural significance in the piers and abutments.
Visual setting and context	Differing land ownerships limit the influence that Roads and Maritime might have on any changes to the visual setting outside of the curtilage. The presence of potential archaeological deposits restricts work in some areas, thereby influencing construction methodologies for essential maintenance works.	The visual setting and context for the bridge could be greatly enhanced if the overgrown vegetation were removed from the road approaches and from the existing interpretive signage and if the bridge were reopened to traffic. There may be further opportunities for enhancement by further interpretation.

6. Development of conservation policies

6.1 Current management context

Monkerai Bridge is currently in very poor condition and is at risk of collapsing under its own self weight or being washed away in a flood. It is held up by various temporary props, but these props also add to the flood risk. The geometry of the bridge is so distorted from its original that it is impossible to repair the bridge piece by piece – it must be reconstructed again from the ground up. Some elements can be reconstructed exactly to their original design, but other elements cannot either due to unavailability of materials, impossible physical constraints or WHS legislation. Some elements as originally designed are capable of taking todays heavy loads while others are not, and so strengthening of some form must be introduced prior to the bridge being reopened.

Natural Heritage Principles is a document prepared by OEH in recognition that the environmental heritage of NSW includes natural as well as cultural heritage, and that the recognition of the value in conserving our remaining natural heritage is vital in order to kerb the accelerating rates of extinctions of plants and animals, and of modifications to the natural environment.[135]

Although Monkerai Bridge is not in a natural heritage area, it was originally constructed with timber obtained from old growth hardwood forests in NSW, which were even then becoming endangered. The timbers originally used would have been derived from 200 year old trees in order to achieve the necessary strength, stability, durability and dimensions. Unfortunately, the timber in the bridges does not last as long as it takes to grow a new tree of the appropriate species and age.

While Allan introduced a number of initiatives in his 1893 design to maximise durability of timber in timber truss bridges, the earlier Old PWD and McDonald trusses have timbers in shapes (large sections containing heart) and configurations (laminated timber bottom chords and heavily notched diagonals susceptible to splitting) which are inherently less durable. Originally, the primary timber components in Old PWD type timber truss bridges sometimes lasted up to 50 years, whereas today those same components rarely last more than 25 to 30 years. The primary difference is the quality of timber available today. Another contributing factor is that the timber truss bridges were often constructed after the entire surrounding area had been cleared of trees (either for farming or sometimes in order to construct the bridge), thereby reducing the termite risk at the bridge.

There are some very clever modern engineered wood products available today which provide substantial strength and durability using imported sustainably grown preservative treated softwoods combined with glass-aramid or carbon-aramid fibres glued together with modern epoxies. However, these are not as strong or as durable as the original ironbark timbers used, and their use would detract substantially from the heritage value of the bridge, a large part of which is the incredible NSW hardwoods which are the very reason for the bridges being constructed.

The elements which demonstrate the unique strength and durability of the NSW hardwoods are the primary load bearing truss elements (top and bottom chords, principals and diagonals).

Round timber girders, sawn timber cross girders and timber piers and abutments have been used in bridges all around the world making use of many different species (both hardwoods and softwoods) which are considerably less strong and less durable than the NSW hardwoods.

[135] *Natural Heritage Principals*, Heritage Information Series, NSW Heritage Office, 2000

These elements are therefore not able to demonstrate the unique strength and durability of the NSW hardwoods, and do not contribute substantially to the cultural significance of a timber truss bridge. In order to achieve a balanced approach to conserving both natural and cultural heritage, and to maximise future stocks of NSW hardwoods available for maintaining timber truss bridges, it is appropriate to consider replacing timbers of little heritage value with other materials such as steel.

6.2 Routine repair works

Routine repair and maintenance works generally required on timber truss bridges are included in the table on the following page. Regular inspections, tightening of bolts, termite treatments and upkeep of good quality protective paint systems are essential for long term conservation.

In the Old PWD truss, some connections are susceptible to damage from overstress. These include the cast iron shoes which are susceptible to sudden brittle fracture without warning. The bolted connections in the laminated timber bottom chord are generally also overstressed, and signs of overstress include longitudinal gaps opening at laminate butt joints or sagging of the truss. The keyed connections between the butting blocks and bottom chords are also highly stressed and initial signs of failure would generally include splitting of the timber along the shear plane.

Timely replacement of deteriorated timber elements is also necessary in order to keep the bridge in a safe and serviceable condition and minimise spread of deterioration to other elements. The primary natural agencies causing the deterioration of timbers include rot, termites and fire.

Rot is largely inevitable in timbers containing heart, and most of the timbers in the Old PWD truss contain heart today because timbers of those dimensions without heart is not available. Rot occurs in trusses most frequently where water accumulates. In the Old PWD truss, the following areas are particularly susceptible to rot in addition to heart rot and inspections should focus here:

- Tops of top chords and butting blocks if water is allowed to pond on horizontal surfaces
- Interface between butting block and bottom chords especially near notched connections
- Interfaces between timbers in the laminated timber bottom chord
- Interfaces between diagonals where they connect in the centre
- Bases of principals at interface with cast iron shoe
- End grain of all large timbers containing heart

The best prevention of rot is use of well-seasoned NSW hardwood timbers (excluding heart where possible) with the highest levels of natural durability and to apply frequent and careful painting.

Termites are major destroyers of timber. It can take three to five years for a new colony of termites to become established enough to damage bridges, but termite colonies are extremely difficult to locate at this early stage. In order for termites to establish a colony, they require food (decaying timber), shelter and moisture, and so moist timber or timbers in moist ground are favoured nesting areas for new termite colonies. Large bridge timbers containing heart (such as truss span cross girders or approach span girders) that have deteriorated are excellent sites for termite nest establishment, especially those that have formed large checks in the top surfaces causing them to become water reservoirs. It is practically impossible to eliminate all termites from a timber bridge, so the aim is to contain termite activity to a level considered economically acceptable by:

- Annual inspections of the bridge for active termites conducted between October and December, and including treatment of any active termites found in the timber members.
- Follow-up inspections before April of the following year focusing on those members treated to ascertain the success of that treatment and to apply additional treatment where required.
- All inspections and treatment of termites conducted by a suitably experienced and qualified person who is familiar with the tell-tale signs of active termite activity and the likely locations for such activity, who can distinguish between destructive and harmless termite species, who can correctly and appropriately install and monitor termite monitoring dowels and termite baits, who can correctly and appropriately apply termite dust, and who can accurately and clearly record and report on termite activity, locations and treatments.

Fire damage is relatively rare on timber truss bridges, and the hardwoods generally used are slow to burn so that only very few timber truss bridges have been lost due to fire. However, many have been damaged due to fire, requiring temporary closures and significant maintenance work, and the risk of this can be reduced by vegetation control in the vicinity of the bridge to form a fire break.

	Every year	Every three years (in addition to every year)	Additional works (as required or specified)
Site & general	Remove any debris and rubbish from the site Clear any vegetation in the area that contributes to a fire hazard or obstructs views Inspect all timber and treat any active termites		Check camber of trusses and re-camber as necessary
Truss timbers containing heart	Remove any accumulations of dirt or fauna (with appropriate environmental approvals)	Check for paint damage, clean and repaint as necessary Tighten all bolts	When timber requires replacement due to deterioration (approx. 25-30 years), replace with new timber sized according to original design drawings
Cross girders containing heart	Remove any accumulations of dirt or fauna (with appropriate environmental approvals)	Check for paint damage, clean and repaint as necessary Tighten all bolts	When timber requires replacement due to deterioration (approx. 20-25 years), replace with new timber sized according to original design drawings
Truss span metal components		Check for paint damage, clean and repaint as necessary	If damage occurs to original fabric then new metal components should be fabricated to precisely match originals

	Every year	Every three years (in addition to every year)	Additional works (as required or specified)
Approach span timber girders containing heart and sapwood	Remove any accumulations of dirt or fauna (with appropriate environmental approvals)	Tighten all bolts Remove any deteriorated sapwood Provide anti-split bolts at corbels as necessary	When timber requires replacement due to deterioration (approx. 20-30 years), replace with new timber sized according to original design drawings
Timber decking	Sweep bridge if required	Tighten all bolts Reseal if necessary	When timber requires replacement (approx. 10-20 years), replace with new timber
Timber railings	Ensure good delineation is maintained by reflectors and paint Check for incident damage, repair and report as necessary	Check for paint damage, clean and repaint as necessary Tighten all bolts	When timber requires replacement (approx. 10-15 years), replace with new timber
Timber piers and abutments	Remove any accumulations of dirt or fauna (with appropriate environmental approvals)	Tighten all bolts	When timber requires replacement (approx. 15-30 years) engage a suitably qualified and experienced engineer to design new substructure

6.3 New work

As has been described above, new work is inescapable for this bridge due to its poor condition and due to the substantial unsuccessful modifications which have already been made to the bridge in the past, negatively affecting both cultural significance and capacity. The purpose of this section is to explain and demonstrate how the various constraints and opportunities interact with the statement of significance, and how these in turn influence the policy approach to be taken. A range of conservation options are canvased, with the most desirable being highlighted, and then a summary of heritage implications of the most preferred option is provided at the end of this section.

Clause 22.1 of the Burra Charter states that, “New work such as additions or other changes to the place may be acceptable where it respects and does not distort or obscure the cultural significance of the place, or detract from its interpretation and appreciation” and notes that new work should respect the significance of a place through consideration of its siting, bulk, form, scale, character, colour, texture and material. Clause 22.2 states that, “New work should be readily identifiable as such, but must respect and have minimal impact on the cultural significance of the place”.

6.3.1 Truss spans

The cultural significance of the bridge is found primarily in the trusses so it is critical that any new work on the bridge does not detract from the interpretation or appreciation of the Old PWD trusses. However, timber truss bridges as originally designed are unable to adequately demonstrate the strength and durability of the materials or the design without remaining a vital part of the NSW road infrastructure, which necessitates some elements being strengthened as vehicular loads increase.

Old PWD trusses have been the most misunderstood of the timber truss bridges, and this has led to modifications which have substantially reduced safety, serviceability and capacity. Design of conservation and strengthening works should look to the original design (which performed well and which is culturally significant) rather than attempting to conserve failed strengthening attempts.

Original feature	Consideration of options
Truss geometry	Existing truss span lengths and locations are close to original, but original should be accurately restored. Existing truss geometries are different to original due to deterioration, sagging, replacement of elements, additions of new elements, shrinkage of timber. Original truss geometries should be restored rather than conserving a deteriorated geometry. Original truss geometry included eccentricity which causes high stresses in some members (top chords and principals). Original truss geometry should be conserved despite eccentricity because changes to truss geometry would have an unacceptable impact on heritage (the eccentricity is unique to the Old PWD and distinguishes it from the McDonald).
Truss timbers (excluding bottom chord)	All truss timbers should be of original dimensions (read off original design drawings) except for the bottom chord which requires strengthening (see next page). Heart free timbers of such large dimensions are not available, so boxed heart timber will have to be used. This means that the timber will not be as durable as the timber originally used, and will necessitate more frequent closures due to maintenance as deteriorated timbers require replacement. Other options considered include using double timber members bolted together for top chords and principals, but this does not provide sufficient strength, does not significantly increase durability, and would also have an unacceptable impact on heritage (the use of large cross-section long timbers is fundamental to the Old PWD truss and distinguishes it from McDonald, Allan and later trusses, the use of double instead of single members for top chords and principals would have a negative impact on historical, associational, aesthetic and technical significance, and would also decrease the representativeness of the bridge).

Original feature	Consideration of options
Bottom chords	Original bottom chords are not sufficiently strong and cannot be safely constructed under current WHS legislation due to their continuity over piers, and so require strengthening. A number of different options were considered as follows, with the last option (external steel plate strengthening) being preferred:

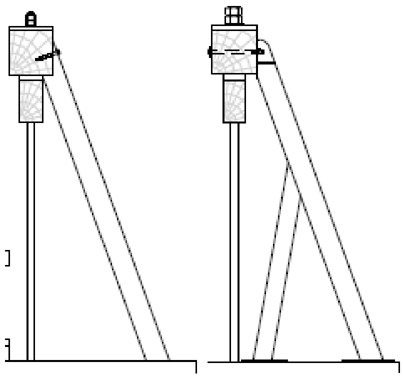
Option	Capacity	Constructability	Heritage
Retain original 3 rows laminated timber 304x304	Fail – insufficient capacity.	Fail – cannot be safely constructed due to length.	Good.
Increase size 3 rows laminated timber 304x400	Fail – insufficient capacity due to connections.	Fail – cannot be safely constructed due to length.	Fail – loss of form – top chords, principals and bottom chord should be same size.
Retain original 3 rows laminated timber 304x304, and introduce Allan truss connections	OK – could be designed to achieve capacity, durability (already poor) would be reduced.	Fail – cannot be constructed due to excessive numbers of rows of steel and timber for bolts.	Fail – introduction of later (Allan truss) technology into earlier truss obscures significance.
Engineered wood products, LVL and glulam	Fail – products use softwood not hardwood and require significant increases in size.	Fail – cannot find supplier in Australia and cannot transport long lengths from overseas.	Fail – use of NSW hardwood (not softwood) timber is fundamental to the significance of the trusses.
Strengthening with internal steel plates	Fail – inserting steel means timber laminates are no longer acting as a unit and cannot carry load.	OK – has been done before, but with difficulty (Junction Bridge, McDonald truss).	Fail – timber in bottom chord becomes non-structural facia and so heritage significance is lost.
Strengthening with internal steel box replacing central laminate	Fail – tension rods located at centre of bottom chord leave insufficient room for internal steel box.	OK – has not been done before, and would be difficult due to numerous connections.	Fail – timber is purely facia and so heritage significance is lost.
Under-trussing with steel rope or Carbon FRP	Fail – thermal movements in steel, lack of stiffness in FRP make these ineffective – also flood debris trap.	OK – has been done before, but difficult to maintain.	Fail – significant visual impact causes loss of clarity and difficulty in interpretation.
Strengthening with external steel plate keeping original dimensions	OK	OK – has been done before (Galston Bridge, McDonald truss)	OK – timber remains structural, form (size) not changed. Laminate layout remains as original.

Original feature	Consideration of options
Cast iron shoes	Some of the cast iron shoes on the truss spans appear to be original, although some have been replaced and many are broken or damaged. Original cast iron shoes are brittle and subject to sudden failure. For the top chord shoes, this susceptibility to brittle fracture poses an unacceptable safety risk because certain forms of failure of the shoe would cause failure of the truss, as has happened on other Old PWD trusses in the past. However, the brittle fracture of the bottom chord shoe, while certainly not ideal, does not pose the same safety risk. One option considered was to retain those of the existing bottom chord shoes which are original fabric. However, there are two primary problems with this: • A number of the original shoes are broken, and therefore they cannot provide restraint against lateral movements of the principal or butting block as they were originally designed, so another restraint system would have to be introduced if these broken original shoes were to be retained in service. • Although it is impossible to see the shoes due to them being obstructed by the current modified bottom chord, the evidence from the photographs available indicate that at least some of the original shoes have been modified in such a way that their distinctive tear-drop shape has been lost, and therefore even if the bottom chord were restored to the original configuration, the original bottom chord shoes could not be properly seen or understood. A representative sample of original shoes is best retained as part of a timber truss bridge moveable heritage collection to be managed by Roads and Maritime. For these reasons, both top and bottom cast iron shoes should be replaced. Options considered for their replacement include welded steel replicas and ductile cast iron replicas. Although ductile cast iron replicas are significantly more expensive than welded steel, they are more faithful to the original design intent and therefore a better heritage outcome and are proposed for this bridge.
Wrought iron tension rods	None of the tension rods on the truss spans appear to be original. All appear to be steel rather than wrought iron and most appear to be larger than original dimensions. Wrought iron tension rods have insufficient strength to carry current heavy vehicle loading. In the past tension rods in some Old PWD trusses have been replaced with larger steel tension rods all of the same size. This led to the misunderstanding that the original designer did not understand that some tension rods were more highly stressed than others. Therefore, larger steel tension rods are suitable to achieve design loading, but two different diameters (larger and smaller) should be used as per the original design to reflect the original intent.
Wrought iron washer plates	There are three types of wrought iron washer plates as previously described. Most of the wrought iron washer plates appear to be original fabric, but are in very poor condition, having suffered considerable corrosion damage. It is therefore not feasible to keep them on the bridge, but it is feasible to retain a representative sample as part of a timber truss bridge moveable heritage collection. • Sliding wrought iron washer plates: A minor modification is required to the wrought iron sliding washer plates (part of the original top chord shoe) to guard against failure when top chord timber shrinks. They should be replaced with new steel sliding washer plates of the same dimensions but in two pieces. • Bevelled wrought iron washer plates: A minor modification is required to the bevelled wrought iron washer plates to accommodate the upsized tension rods at these locations. They should be replaced with a new machined steel washer plates fabricated to the original dimensions with a slightly larger hole. • Other wrought iron washer plates: These should be replaced with new welded steel washer plates fabricated to the original dimension with enlarged holes.

Original feature	Consideration of options
Wrought iron fish plates	The original wrought iron fish plates have been removed from the bridge. The proposed use of external steel plate strengthening of the bottom chords obviates the need for wrought iron fish plates (the external steel plates themselves form the bolting template for the laminated timber bottom chord). However, these were a unique feature of the Old PWD and greatly assist interpretation and understanding of the original design intent and so should be reinstated on the bridge at the original locations making use of thin steel plate cut to the original dimensions.
Sway braces	The sway bracing is critical for providing lateral support to the truss top chord. The original sway bracing on Old PWD trusses was large section timber sway bracing located at every panel point along the top chord. This has been replaced with ineffective slender steel sway bracing connected to extended cross girders. • Options considered for the sway bracing include: • Restore original sway bracing (excessive shrinkage makes ineffective). • Strengthen existing steel sway bracing (insufficient capacity). • Provide new steel sway bracing with dimensions matching original. The detailing of the sway braces relied on dimensionally stable timber. One of the main reasons for the use of large timbers in the Old PWD truss was because the large timbers were less susceptible to warping and shrinkage. Unfortunately, the old growth timbers originally used are no longer available and so the top chords and cross girders (to which the sway braces connect) are very susceptible to considerable amounts of shrinkage, making the original sway braces ineffective. Because the new top chord timber will contain heart (as the current existing top chords contain heart), there is an inherent weakness along the centre and an inherent tendency to splitting. Bolted connections between the top chord and the sway braces are known from experience to exacerbate this problem. For these reasons, a steel sway brace of the same dimensions as the original timber sway brace, with an additional steel prop for triangulation should be provided. The steel sway brace can be neatly detailed in its connections at the top and base, and the bolts at the top (through the centre of the top chord) detailed with slotted holes so that they do not apply stresses to the timber in such a way that might exacerbate the splitting risk of the top chord when the timber inevitably shrinks. The steel sway brace should be painted white (as the original sway braces were painted white) to indicate / interpret that originally these sway braces were timber, which is a unique feature of the Old PWD trusses.

Figure 6-1 shows the prefered option of the sway brace (right) with an additional steel prop for triangulation compared with the original design (left). The prop is necessary to protect the top chord from stresses which would tend to exacerbate splitting of the timber and to strengthen the sway brace so that it has sufficient capacity to provide lateral restraint to the top chord under modern vehicle loading. Another alternative would be a larger sway brace, but this would have a substantial negative impact on the aesthetics of the bridge.

Figure 6-1: Sway Braces



(source: author)

Original feature	Consideration of options
Cross girders	There are two historical problems with primary cross girders in Old PWD trusses. They have insufficient capacity to carry today's loads, and they have a tendency to shrink which causes loss of truss geometry and overstress of connections. Options considered for truss span cross girders are as follows: • Restore original timber cross girder design (discounted due to issues above). • Install timber cross girders of larger cross section in order to have sufficient capacity to carry today's loads (discounted because increasing the size of the cross girders would necessarily change the geometry of the whole truss in order to fit. Also discounted because larger timber cross girders would experience more shrinkage and so further exacerbate the known issue of loss of geometry due to gaps opening up between diagonals and cross girders). • Strengthen original timber cross girder design with external steel plates somewhat similar to what is being proposed for the bottom chord strengthening (discounted because previous attempts on other bridges have proved to be ineffective because cross girders are stressed primarily in bending whereas bottom chords are stressed primarily in tension). • Strengthen original timber cross girder design with transverse under-trussing (discounted because previous attempts on other bridges have proved to be ineffective due to the tendency for under-trussing to loosen and fall off). • Provide steel wedges between the timber cross girders and the truss in order to take up the slack when the timber cross girders shrink, discounted because: a) this was an innovation by McDonald unique to the McDonald truss and so to put it into an earlier truss type confuses interpretation b) the geometry of the trusses would require modification in order to fit in this addition and that would degrade its representativeness, and c) this option does not address the problem of the lack of capacity without also increasing the size of the cross girders. A previous concept for the rehabilitation of Monkerai Bridge included very large steel brackets around each primary cross girder attached to the timber diagonals on each side and bolted to the bottom chord in an attempt to reduce the shrinkage problem (discounted due to substantial visual impact, substantial changes to original design intent regarding flow of forces, and ineffective in providing capacity required for today's loads). In addition to the two known historical problems with timber cross girders (under-capacity and shrinkage), the timber cross girders are also incapable of supporting a complying traffic barrier. In order for a safe and complying steel traffic barrier to be effective, it must be solidly connected to something, and it is not possible to achieve a strong enough and rigid enough connection in timber. Therefore, it is proposed to replace the timber primary cross girders with steel box sections of the same dimension as the original. By doing this, the strength is sufficient, the shrinkage is done away with, the traffic barrier has something to connect to, and the form and function of the original primary cross girders is restored, as well as the form, fabric and function of all other truss members. Depending upon the decking configuration, there may be no need to make any modifications from the original design for the timber secondary cross girders. The existing timber secondary cross girders are in generally poor condition as well as varied sizes and lengths and are not notched over bottom chords as originally designed. Assuming a suitably strong deck is provided, all secondary cross girders should be replaced with new timbers of original dimensions and detailing in original locations as marked in the original design drawings.

<table>
<tr><th>Original feature</th><th>Consideration of options</th></tr>
<tr><td>Decking</td><td>
The original deck on Monkerai Bridge truss spans consisted of tightly spaced diagonal decking 100mm thick, attached to cross girders and spiking planks (sometimes also called stringers) by means of vertical iron spikes hammered from above with a black tar seal. There were no kerbs on truss or approach spans.
The original timber deck has insufficient capacity to carry current loads. A study of all available drawings for Old PWD trusses designed by William Christopher Bennett (the designer of the Old PWD) shows that the diagonal decking is not essential to the design as a number of different deck types were used, including:

thick transverse decking spanning from truss to truss (no cross girders at all)
transverse decking on longitudinal stringers (no secondary cross girders)
transverse decking on longitudinal stringers spanning secondary cross girders

Significant modifications to the deck have occurred over time, with the deletion of the spiking planks, the introduction of a kerb, the replacement of iron spikes with steel bolts, the introduction of spacing between planks for drainage, the introduction of longitudinal timber sheeting, and the covering of the deck with a sprayed seal. These modifications are intrusive to the heritage significance. Even with all these modifications, the current timber deck is still problematic:

Insufficient lateral stiffness to keep bottom chords and trusses aligned
Insufficient lateral stiffness to provide load path for traffic barrier impact
Insufficient strength to span between primary cross girders, thereby necessitating upsizing or other strengthening of secondary cross girders
Safety issues for vehicles due to slipperiness and protruding loose bolts
Safety issues for cyclists due to shrinkage gaps and roughness
Safety issues for pedestrians due to trip hazards
Community issues due to excessive noise when planks become loose
Community inconvenience due to regular bridge closures required to maintain the deck, and also length of closures required for full deck replacement (every 7 years for sheeting and every 15 years for decking and sheeting).

For these reasons, a stress laminated timber (SLT) deck is preferred for Monkerai. An SLT deck restores the original form (very smooth tightly spaced, black from above) the original type of fabric (made from NSW hardwoods) and the original function (is able to safely carry traffic and provide lateral stability to the trusses). Some options that were considered with regard to the SLT decking include:

It cannot be laid diagonally to better acknowledge the original decking because the performance of an SLT deck is dependent upon having strands run transverse to the deck and laminates run longitudinally. Previous attempts at different orientations have proved to be very problematic and ineffective.
Original diagonal decking cannot be retained under or above the SLT as the weight overloads the truss and is problematic also for SLT deck connections.

An SLT deck not only provides a safe surface for all bridge users and minimised community inconveniences due to noise and closures, but it also obviates the need for other changes which would otherwise be necessary on the truss spans:
Without an SLT deck, underdeck steel bracing would have to be introduced to provide lateral stiffness, and this would overload the bridge and also obscure views to the diagonal decking which could only be viewed from beneath.
Without an SLT deck, the secondary cross girders would require strengthening either upsizing or (more likely) by replacement with steel cross girders.
The retention of the laminated timber bottom chord (strengthened with steel plates) is structurally dependent upon the deck providing lateral stiffness.
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6.3.2 Approach spans

Approach spans have little significance and even if they were reconstructed exactly to their original design, they would still only have little significance. The approach span originally consisted of five equally spaced longitudinal timber girders per span (the centre three being round and the outer two being sawn) with tightly fitted transverse timber decking. The general form of the timber girders and corbels remains, but the details have been modified, including substantial modifications to the carpentry and connection details of the girders and corbels, the loss of the original timber shear keys at the interfaces, the addition of numerous bolts through the girders and in the deck, the introduction of a kerb, the replacement of iron spikes with steel bolts, the introduction of spacing between planks for drainage, and the introduction of longitudinal timber sheeting.

Unfortunately, the original timber girder design cannot be restored for three reasons. The first reason is that the timber girders of the approach spans do not have sufficient capacity for today's loads, especially considering the long span lengths required and the limited capacity of the girders.

The second reason is safety, timber spans even with current modified detailing, are problematic:

- Timber girders with timber decks cannot support a complying traffic barrier
- Safety issues for vehicles due to slipperiness and protruding loose bolts
- Safety issues for cyclists due to shrinkage gaps and roughness
- Safety issues for pedestrians due to trip hazards

The third reason is the difficulty in obtaining sufficiently long girders and the impossibility of maintaining the original detailing of girders, corbels and decks without constant community inconveniences due to excessive noise and bridge closures to replace deteriorated elements.

Description of option	Considerations
Provide round timber girders similar to original, introduce SLT deck and steel cross girders	This has been done with some success on two timber truss bridges (Abercrombie and Wallaby Rocks, both Allan trusses) and has the advantage of retaining longitudinal timber girders in the approaches and a timber deck. Although this may be feasible on some bridges, this is not possible at Monkerai due to the geometrical constraints inherent in the Old PWD and McDonald trusses, whereby the deck sits directly on the cross girders (there are no longitudinal stringers on the truss spans) which means that there is not sufficient space to fit the steel cross girders between the SLT deck and the timber girders. The other geometrical constraint is the extension of the truss bottom chords and corbels well beyond the pier, which is again a feature of the earlier truss types. Furthermore, even if the approach spans are made shorter to reduce the stress in the longitudinal timber girders, the sawn outer girders do not have sufficient capacity and so would have to be round. The aesthetic is further compromised by the necessity of providing an external galvanised steel monorail for access and maintenance which obscures the view of the timber girders from the side. For these reasons, this option was discounted for Monkerai Bridge.

Description of option	Considerations
Provide timber concrete composite decks.	This has been done on some bridges (e.g. Hinton and Morpeth Bridges), although there have been some issues with the design leading to spitting of timber and opening of gaps between timber and concrete. A modified timber concrete composite deck was therefore developed based on the more effective Maria River Bridge. These have the advantage of including at least some structural timber in the approach spans, although they also introduce a lot of concrete. Unfortunately the introduction of concrete, with its inherent thermal movements, causes significant structural difficulties at Monkerai Bridge which led to modifications required on piers and the truss span, and so this option too was discounted.
Provide steel concrete composite deck	This has been done on some bridges (e.g. Coonamit and Barham), and this option has the advantages of strength (can span longer between piers than other options and so would allow for approach span piers to be reconstructed in their original locations rather than moved), durability (has a 100 year design life, whereas other options are limited to between 30 and 50 year design life) and cost (is cheaper both in construction and for maintenance than other options). However, similar to the timber concrete composite solution, the introduction of concrete, with its inherent thermal movements, causes significant structural difficulties at Monkerai Bridge which led to modifications required on piers and the truss span. Also, this option would leave no timber in the approach spans, which would be a particularly poor outcome for an Old PWD truss which, out of all the truss types, used the maximum amount of timber in the bridge.
Provide steel girders and steel cross girders with SLT deck	This has been designed for some bridges (e.g. Glennies Creek and Elderslie), and this option has the advantages of strength (the steel girders can be designed to span a sufficient length to obviate the need for additional approach span piers) and durability (the SLT deck on steel girder has a 50 year design life). The use of an SLT deck continuous along the whole bridge (including approach spans and truss spans from abutment to abutment) provides a load path for longitudinal braking forces (which would otherwise necessitate significant changes to the timber piers) as well as assisting with traffic barrier impact loads and flood loads, thereby minimising other changes to the bridge and preserving something of the original continuity which existed along all the spans of the bridge. The proposed approach spans, although not original, seek to conserve or enhance the heritage significance of Monkerai Bridge in the following ways: • Provision of a structurally sound approach span which minimises bridge closures and allows all the required vehicles to use the bridge should improve the social significance of the bridge which is currently very low (intrusive). • Replacing the existing approach spans with spans which are clearly modern enables better interpretation of the bridge, as currently the approach spans are intrusive with respect to representativeness due to the fact that the details are not original but they are also not clearly new, thereby giving a false impression that all these problematic details are part of the original design. • The use of a continuous SLT deck retains a form of smooth and tightly packed timber decking with a black seal for the whole length of the bridge which would be very similar to the aesthetic of bridge deck as it was originally constructed.

Description of option	Considerations
	• The approach spans should be designed to minimise the visual intrusiveness of the steel girders by designing them to be as visually recessive as possible (e.g. a larger number of smaller girders to minimise the depth of the steel in the approach spans so that the truss spans remain the dominant feature of the bridge, since the truss spans are the reason that this bridge is significant). • New work is to be identifiable as such as stated in the Burra Charter – it is not possible to restore the original design because of issues with structural capacity (especially of the outer sawn girders, which are important both to the aesthetic and to the function of the original design), issues with availability and durability of materials, and because of the need for new traffic barriers. Other efforts to include a form of timber girder in the approach spans look clunky when compared with the original design, but are not clearly a modern design either, and therefore detract from the significance of the Old PWD. The proposed approach span treatment has the advantage of being neat and visually recessive and so not detracting from the significance of the truss.

6.3.3 Piers and abutments

Historically, the most common cause of structural failure (collapse) of timber truss bridges has been flood damage to the piers and abutments. Although there are some rare instances where overloaded vehicles have caused timber truss bridges to collapse, there have been many timber truss bridges that have lost whole spans due to flood damage. Bridges with timber trestle piers are particularly susceptible to flood damage due to the prevalence of hidden deterioration in the timber piles and limited capacity in bolted timber connections. It is critical for the conservation of Monkerai Bridge that the substructure be kept sufficiently strong to resist likely future flood loads.

The timber piers and abutments are of little cultural significance with alterations detracting from significance and making the bridge as a whole more difficult to interpret. None of the visible fabric is original, except for perhaps a couple of metal straps on one of the abutments, and it would be physically impossible to restore the original configuration of piers and abutments.

A recent flood study indicates that Monkerai Bridge is completely inundated in the 1 in 100 year flood event (shown in yellow in Figure 6-2), meaning that the bridge is at relatively high risk of damage due to floods, and special attention must be paid to the piers and abutments to manage this risk.[136]

[136] Roads and Maritime, Bridge over Karuah River at Monkerai, Estimation of Flood Level, November 2016.

Figure 6-2: Flood study results for Monkerai Bridge.

(source: Roads and Maritime Report 2016)

Although it is generally stated that there is no “original fabric” when it comes to timber in bridges, this only applies to visible and accessible fabric. The timber piles well below ground level are almost certainly the original timber piles driven there in the very early 1880s. The current timber piles seen above ground level would be spliced to those original piles by an underground connection. Unfortunately, these timber to timber buried splices do not have anywhere near the original capacity or durability and therefore pose an unacceptable risk to the bridge.

Timber piles rot below ground level and are impossible to replace because before a new timber pile can be driven, the old timber pile would have to be removed, and this is generally not possible.

Of all the details of the bridge, the original details of the piers and abutments are the least certain because we have neither old photographs nor original drawings for the substructure as constructed. Article 20.1 of the *Burra Charter* states that, “Reconstruction is appropriate only where a place is incomplete through damage or alteration, and only where there is sufficient evidence to reproduce an earlier state of the fabric.” Although the substructure at Monkerai Bridge meets the first part of the criteria for reconstruction (i.e. it has been altered), it does not meet the second part because there is not sufficient evidence to reproduce the original.

Options considered for the substructure (piers and abutments) at Monkerai Bridge include:

- Restore original design (discounted due to impossibility as outlined above).

- Do nothing but keep the current configuration of piers and abutments and continue like for like maintenance approach (discounted because the piers and abutments as currently constructed leave the bridge at risk of serious flood damage, they are also visually intrusive and damaging to the representativeness of the bridge as an example of 1880s detailing).
- Relocate the bridge (and therefore the piers and abutments) in order to allow new timber trestle piers and abutments to be constructed as per the most likely original design (discounted because there is a significant heritage impact in moving the bridge from its original and existing location, and this solution is not sustainable because the bridge would have to be relocated again and again approximately every 25 years due to deterioration).
- Retain bridge in current location and restore the capacity of substructure by replacement with new piers and abutments designed to withstand flood loads and avoid existing piles.

Given that the piers and abutments have little heritage significance and that even if they were reconstructed exactly to their original design, they would still only have little significance, the final option (replace existing piers and abutments with new piers and abutments) is preferred.

Abutments

There is really only one option for the abutments, and that is to construct new concrete abutments. This was in fact the original detail for some timber truss bridges (e.g. Morpeth Bridge and the timber truss bridge over Crookwell River) and has been subsequently done on a number of other timber truss bridges (e.g. Barham Bridge and Becker's Bridge). On some bridges (not timber truss bridges) attempts have been made to hide the concrete abutments with a layer of timber facia (e.g. Dalgety Bridge), but this is poor heritage practice (note to Article 22 of the *Burra Charter* states that imitation should generally be avoided) as well as a poor structural outcome (the connections for the timber facia as well as the presence of the timber facia collect moisture, attract termites and give a poor visual outcome with time as deterioration of timber and corrosion occurs).

Another option considered for minimising the visual impact of the concrete abutments is to replace the current retaining-wall-type abutments with spill-though-type abutments, which have a much smaller exposed area of concrete. Unfortunately, at Monkerai the hydrology is such that spill through abutments are not possible at this site. Therefore, efforts have been made to minimise the size of the abutment and to keep them as neat and visually unobtrusive as possible. An additional conservation benefit of introducing concrete abutments is that these separate the timber truss from the ground, and therefore provide some protection from termite attack (in addition to the regular inspections and termite treatments which are done). This is especially important on the Old PWD and McDonald truss where the timber for the trusses is becoming increasingly difficult to source.

Piers

There are two broad options for the piers, each with various advantages and disadvantages. In considering options for the piers, careful attention has been given to form, fabric and function. One option is to maximise the retention of fabric (i.e. timber), which must necessarily change the form and the function of the different elements. Another option is to maximise the retention of the form and function (i.e. configuration and flow of forces), which must necessarily change the fabric. Considerable difficulty is faced in designing timber trestle piers in for high velocity flood waters without the advantages of the structural robustness of continuous driven timber piles. Analysis has been undertaken, and concepts prepared to ensure mitigation against flood loads. The two concepts are compared with the original configuration and the existing in the table below.

Pier	Best guess at original	Existing	Option A maximise retention of timber fabric	Option B maximise retention of form & function
1	3 round piles 2 single braces 1 double wale 1 timber headstock	Hidden concrete 3 round piles spliced 1 double brace 0 wales 1 timber headstock	Concrete foundation 5 sawn columns with steel brackets 2 single braces 1 double wale 1 timber headstock	Concrete foundation 3 steel UC columns 2 single PFC braces 1 double PFC wale 1 UC headstock
2	3 round piles 2 single braces 1 double wale 1 timber headstock	Hidden concrete 2 round piles spliced 1 sawn pile spliced 2 single diagonal braces 0 wales 1 timber headstock	Concrete foundation 5 sawn columns with steel brackets 2 single braces 1 double wale 1 timber headstock	Concrete foundation 3 steel UC columns 2 single PFC braces 1 double PFC wale 1 UC headstock
3	6 square sawn piles 2 single braces 1 double wale 1 timber headstock	Hidden concrete 6 sawn piles spliced 2 single braces 1 double wale spliced 1 timber headstock	Concrete foundation 3 sawn columns with steel brackets 4 round columns with steel tubes 2 double braces with steel brackets 0 wales 1 timber headstock	Concrete foundation 6 steel UC columns 2 single PFC braces 1 double PFC wale 1 UC headstock
4	6 square sawn piles 2 single braces 1 diagonal strut 1 double wale 1 timber headstock	Exposed concrete 6 sawn columns spliced 4 sawn columns propped 2 single braces 1 diagonal strut 1 single sill beam 0 wales 1 timber headstock	Concrete foundation 2 sawn columns with steel brackets 4 round columns with steel tubes 2 double braces with steel brackets 0 diagonal struts 0 wales 1 timber headstock	Concrete foundation 6 steel UC columns 2 single PFC braces 1 diagonal UC strut 1 double PFC wale 1 UC headstock
5	6 square sawn piles 2 single braces 1 diagonal strut 1 double wale 1 timber headstock	Exposed concrete 6 sawn piles spliced 4 round columns propped 1 double brace spliced 1 diagonal strut spliced 1 double wale 1 timber headstock	Concrete foundation 3 sawn columns with steel brackets 4 round columns with steel tubes 2 double braces with steel brackets 0 diagonal struts 0 wales 1 timber headstock	Concrete foundation 6 steel UC columns 2 single PFC braces 1 diagonal UC strut 1 double PFC wale 1 UC headstock

Clause 22.1 of the Burra Charter states that, “New work such as additions or other changes to the place may be acceptable where it respects and does not distort or obscure the cultural significance of the place, or detract from its interpretation and appreciation” noting new work should respect the significance of a place through consideration of its siting, bulk, form, scale, character, colour, texture and material. These are used to compare the two options here:

Burra Charter	**Option A** **maximise retention of timber fabric**	**Option B** **maximise retention of form & function**
Siting	Piers 3, 4 & 5 reconstructed in situ Piers 1 & 2 relocated to avoid old piles	Piers 3, 4 & 5 reconstructed in situ Piers 1 & 2 relocated to avoid old piles
Bulk	Bulk of concrete increased to avoid old piles (wider concrete foundation) Bulk of Piers 1 & 2 increased due to requirement for additional columns Bulk of Piers 3, 4 & 5 increased due to requirement for double bracing	Bulk of concrete increased to avoid old piles (wider concrete foundation) Original bulk of all piers restored, size and configuration of elements as original
Form	Introduction of concrete base Form of Piers 1 & 2 modified by increased number and different shapes & arrangement of columns and introduction of steel brackets at base for connections Form of Pier 3 modified by different shapes of columns, introduction of various tubes and brackets for connections, deletion of wales and introduction of extra braces Form of Piers 4 & 5 modified by different shapes of columns, introduction of various tubes and brackets for connections, deletion of diagonal strut & wales and introduction of extra braces	Introduction of concrete base Shapes of all elements modified from timber to steel UC (universal column) or PFC (parallel flanged channels). General form, being size, locations and configurations of all elements as original
Scale	Increased somewhat due to concrete	Increased somewhat due to concrete
Character	The original piers were elegant in their slenderness and simplicity, introduction of various metal elements and differing shapes of timber elements increases the complexity and bulk of the piers so that they are no longer slender and simple.	The original piers were elegant in their slenderness and simplicity and these characteristics are preserved
Colour	The original piers were unpainted timber which varied in colour from brown to grey, but was largely homogeneous. The introduction of many different materials (concrete and steel as well as timber) means that the homogeneity of colour is lost – colour will remain dark grey/brown	The original piers were unpainted timber which varied in colour from brown to grey, but was largely homogeneous. The use of fully steel piers retains the homogeneity of colour either painted dark grey or making use of weathering steel to give a natural brown colour.
Texture	Some timber texture is retained, but new concrete and steel is also introduced	The timber texture is removed and new concrete and steel is introduced
Material	Much timber is still used, but also large amounts of concrete and steel introduced	Steel and concrete substituted for timber

On the basis of this analysis, new steel trestle piers on concrete foundations should be provided.

6.3.4 Traffic Barriers

Timber rails do not have any ability to prevent a vehicle from falling off the bridge. On the contrary, timber rails are a spearing risk to errant vehicles and their passengers. There have been a number of instances of vehicles driving off the sides of timber truss bridges, with some fatalities. Roads and Maritime has a legislative responsibility for the safety of the travelling public and it is therefore necessary that Roads and Maritime do what it can to mitigate this well known risk.

A number of different approaches to barrier rail design have been investigated in attempts to minimise the visual impact and obtrusiveness on heritage bridges. The barrier proposed for Monkerai Bridge is not designed to meet the current Australian Standard (AS 5100-2017), but an earlier standard (AUSTROADS-96). The geometrical requirements and the design loads are significantly less stringent in AUSTROADS-96, which is the absolute minimum required to keep a small errant vehicle safe. The traffic barrier must provide safety not only for errant vehicles, but also for pedestrians, cyclists and workers (particularly inspection and maintenance personnel).

Description of option	Considerations
Typical steel ordnance style barrier	The two structural rails are generally kept to the minimum possible size to be effective (150mm x 100mm at this bridge) and a large kerb (150mm x150mm) is provided just clear of the deck to imitate the existing timber kerb while also allowing for drainage and having some capacity to redirect errant vehicles. The top rail, which is not part of the traffic barrier, but is a handrail, has generally been detailed to reflect the shape, size and orientation of the original timber top rail which was present the later types of timber truss bridges. The typical steel ordnance style barrier is generally galvanised and then painted white. The white colour is used to imitate the original white timber ordnance rail, and has the additional safety advantage of providing clear delineation. The advantage of this option is that it seeks to provide a level of interpretation of the original ordnance rail which was often used on timber bridges. The disadvantages of this option include the following: • The bulk (volume) of the steel barrier is more than 3.5 times greater than the bulk of the original timber rails at Monkerai Bridge, and this increase in bulk has a significant visual impact on the bridge. • The white paint on the steel further accentuates the barrier more than the timber truss due to the fact that the light tends to reflect more brightly from painted steel than from painted timber, so this further detracts from the ability to clearly see and interpret the trusses. • There was originally no kerb on truss spans or approach spans of Monkerai Bridge, so this kerb is interpreting something which was a later introduction. • There was originally (and there is still) no top rail on the Old PWD trusses as these were introduced on truss spans only in the Allan truss.
Modified RMS steel ordnance style barrier with no kerb	An option for Monkerai Bridge was developed which attempted to reduce the bulk of the typical RMS steel ordnance style barrier by removing the kerb (especially since there was originally no kerb on the bridge) and tidying up some connection details to reduce the visual clutter of the barrier system. Unfortunately, the bulk (volume) of the steel barrier was still more than 3 times greater than the bulk of the original timber rails, and the issue of steel reflecting through the

Description of option	Considerations
	white paint with excessive brightness was not resolved.
New internally designed steel traffic barrier systems attempting to reduce visual impact.	The primary design difficulty in developing a combined traffic and pedestrian barrier is that the loads for the traffic are an order of magnitude larger than the loads for pedestrians, and so it is difficult to make the barrier look like a single system, rather than a traffic barrier with a pedestrian rail tacked on. Some consideration was therefore given to what other countries have done on aesthetically important bridges to produce the best results, especially bridges in Norway, where there is a very big emphasis on bridge aesthetics. A number of different options where therefore developed based loosely on various bridges in Norway. All of the developed options were able to meet the design criteria of AUSTROADS-1996, but all were still visually intrusive for the bridge.
New architect designed steel traffic barrier system to reduce visual impact.	A number of urban design principles were applied to this design including: • Integrate barrier to create a unified composition • Work toward decluttering the appearance of the bridge • Use a matt grey paint finish to contrast with the white truss In addition to these urban design principles, the same strength and geometrical requirements of AUSTROADS-96 were applied in this design development. A number of concepts were developed and tested using photo montages and 3D computer models to assess the visual impact, and 'Option H' (see Figure 6-3 below) was the option which performed best because, even though it provides less visual permeability, it makes the truss more legible by allowing the two horizontal traffic barrier rails to read as a single element. The result simplifies the composition by reducing the complexity, making the truss more dominant.[137] **Figure 6-3: Traffic Barrier.**  *(source: Monkerai Bridge Urban Design Study 2016)*

Given that the timber railings have little heritage significance and that even if they were reconstructed exactly to their original design, they would still have little significance, the final option (new architect designed traffic barrier as shown in Figure 6-3 above) is preferred.

[137] For full report on the development of this option, see *Monkerai Bridge Urban Design Study*, Nov 2016.

6.3.5 Summary of heritage implications of new work

The tables in this section summarise the heritage implications of the proposed new work when compared with the two other broad options of retaining as existing or reconstructing as original.

Truss span top chords and principals	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (reconstruct original)
Historical	High (not carrying traffic)	High (load limit cannot demonstrate strength)	Exceptional
Associative	Exceptional	High – load limit obscures design intent	Exceptional
Aesthetic Technical	Exceptional	High (load limit cannot demonstrate strength)	Exceptional
Social	Intrusive (unable to use due to closure)	Little (unable to use due to load limit and regular closures)	Moderate – reopening bridge to all traffic should enhance social significance
Scientific Archaeological	N/A	N/A	N/A
Rarity	Exceptional	Exceptional	Exceptional
Representative	Exceptional	Exceptional	Exceptional

Truss span bottom chords and butting blocks	Retain as existing	Reconstruct original and impose 5 tonne load limit (impractical – WHS)	Preferred modifications (reconstruct original strengthened with external steel plates)
Historical	Little (short timbers used instead of long)	High (load limit cannot demonstrate strength)	High – demonstrates a key element of the item's significance with alterations designed to enhance and not to detract from significance
Associative	Intrusive (all of Bennett's careful detailing is lost)	High – load limit obscures design intent	Exceptional – restores all of Bennett's careful detailing and strength for current loads
Aesthetic Technical	Intrusive (original aesthetic lost and no strength)	High (load limit cannot demonstrate strength)	Exceptional – restores original aesthetic of a working truss and displays tear drop shaped shoes and fish plates
Social	Intrusive (unable to use due to closure)	Little (unable to use due to load limit and regular	Moderate – reopening bridge to all traffic

Truss span bottom chords and butting blocks	Retain as existing	Reconstruct original and impose 5 tonne load limit (impractical – WHS)	Preferred modifications (reconstruct original strengthened with external steel plates)
		closures)	should enhance social significance
Scientific Archaeological	N/A	N/A	N/A
Rarity	Moderate (one of six remaining timber truss bridges with butting blocks and laminated chord)	Exceptional	Exceptional – would be the only Old PWD truss displaying original bottom chord detailing (this is not possible at Clarence Town due to impossibility of obtaining original lengths)
Representative	Intrusive (lost features of Old PWD and blurred distinctions between PWD and McDonald)	Exceptional	Exceptional – as above
Truss span diagonals and props	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (reconstruct original)
Historical	High (not carrying traffic)	High (load limit cannot demonstrate strength)	Exceptional
Associative	High (Bennett's original design intent is currently only partially reflected)	High – load limit obscures design intent	Exceptional
Aesthetic Technical	Moderate (original aesthetic & technical details partially lost due to over-size notching)	High (load limit cannot demonstrate strength)	Exceptional
Social	Intrusive (unable to use due to closure)	Little (unable to use due to load limit and regular closures)	Moderate – reopening bridge to all traffic should enhance social significance
Scientific Archaeological	N/A	N/A	N/A
Rarity	Exceptional	Exceptional	Exceptional
Representative	High (features present in form [illegible] detailing lost)	Exceptional	Exceptional

Truss span metal components	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (reconstruct original with minor modifications)
Historical	High (not carrying traffic)	High (load limit cannot demonstrate strength)	High – demonstrates a key element of the item's significance with alterations designed to enhance and not to detract from significance
Associative	High (fish plates are completely missing and other items have been modified)	Exceptional	Exceptional
Aesthetic Technical	Moderate (original aesthetic & technical details largely lost)	High (load limit cannot demonstrate strength)	Exceptional – restores original aesthetic of a working truss and displays tear drop shaped shoes and fish plates
Social	Intrusive (unable to use due to closure)	Little (unable to use due to load limit and regular closures)	Moderate – reopening bridge to all traffic should enhance social significance
Scientific Archaeological	Moderate	N/A – original fabric would be removed and samples preserved	N/A – original fabric would be removed and samples preserved off site
Rarity	Exceptional	Exceptional	Exceptional
Representative	High (some items are missing and others have been modified)	Exceptional	Exceptional

Truss span sway braces	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (reconstruct original with minor modifications)
Historical	Intrusive	Little – cannot demonstrate functioning of sway brace due to excessive shrinkage	Moderate – alterations are not original, but designed to demonstrate original form and function
Associative	Intrusive	Little – cannot demonstrate functioning of sway brace due to excessive shrinkage	Moderate – alterations are not original, but designed to demonstrate original form and function
Aesthetic Technical	Intrusive	Little – cannot demonstrate functioning of sway brace due to excessive shrinkage	High – restores original aesthetic and function of sway braces and esthetic of cross girders (original length)
Social	Intrusive (unable to use	Little (unable to use due to load limit and regular	Moderate – reopening bridge to all traffic

Truss span sway braces	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (reconstruct original with minor modifications)
	due to closure)	closures)	should enhance social significance
Scientific Archaeological	N/A	N/A	N/A
Rarity	N/A	Exceptional	N/A
Representative	Intrusive	Little – cannot demonstrate functioning of sway brace due to excessive shrinkage	High – demonstrates original form and function

Truss span cross girders	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (primary in steel, secondary as original)
Historical	Moderate	Moderate – demonstrates original use of timber, but cannot demonstrate working truss due to immediate truss action with shrinkage	Moderate – secondary cross girders as original, alterations to primary cross girders not original, but designed to demonstrate original form and function
Associative	Little (unsightly extensions and loss of detailing, additions)	Little – cannot demonstrate functioning of primary cross girders due to excessive shrinkage	High – demonstrates original form and function and allows the Old PWD truss to work
Aesthetic Technical	Little (unsightly extensions and loss of detailing, additions)	Little – cannot demonstrate functioning of cross girders due to excessive shrinkage	High – restores original aesthetic and function and detailing of primary and secondary cross girders
Social	Intrusive (unable to use due to closure)	Little (unable to use due to load limit and regular closures)	Moderate – reopening bridge to all traffic should enhance social significance
Scientific Archaeological	N/A	N/A	N/A
Rarity	N/A	N/A	N/A
Representative	Intrusive (modified, loss of load paths, loss of truss behaviour)	Little – cannot demonstrate functioning of cross girders due to excessive shrinkage	Moderate – demonstrates original form and function of cross girders and also fabric of secondary cross girders
Approach spans	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (steel girders with stress laminated timber deck)

Truss span cross girders	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (primary in steel, secondary as original)
Historical	Little	Moderate	Little –timber deck indicates history of timber decking
Associative	Little	Little	Little
Aesthetic Technical	Little	Little	Little
Social	Intrusive (unable to use due to closure)	Little (unable to use due to load limits & closures)	Moderate – reopening bridge should enhance significance
Scientific Archaeological	N/A	N/A	N/A
Rarity	N/A	N/A	N/A
Representative	Intrusive	Moderate	N/A

Decking	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (replace with SLT deck)
Historical	Moderate	Moderate	Moderate – still a timber deck
Associative	Little	Little	Little – still timber decking
Aesthetic Technical	Intrusive	Intrusive – shrinkage will change aesthetic soon	Little – restores closer to original aesthetic & function
Social	Intrusive (unable to use due to closure)	Little (unable to use due to load limits & closures)	Moderate – reopening bridge should enhance significance
Scientific Archaeological	N/A	N/A	N/A
Rarity	N/A	N/A	N/A
Representative	Intrusive	Moderate	N/A

Railing	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (replace with architect designed traffic barrier)
Historical	Little	Not possible due to WHS legislation, but would be of only little significance	Little – visually recessive
Associative	Little		Little – still no kerbs
Aesthetic Technical	Little		Little – designed to be visually recessive
Social	Little		Moderate – increased safety
Scientific Archaeological	N/A		N/A
Rarity	N/A		N/A
Representative	N/A		N/A

Piers and abutments	Retain as existing	Reconstruct original and impose 5 tonne load limit	Preferred modifications (replace with steel piers and concrete abutments)
Historical	Little	Not possible due to presence of existing timber piles, but would be of only moderate significance	Little – visually recessive
Associative	Little		Little – restore original form
Aesthetic Technical	Intrusive (less strong, not slender)		Moderate – restore original form and function
Social	Intrusive (unable to use due to closure)		Moderate – reopening bridge should enhance significance
Scientific Archaeological	Moderate		Moderate – new piles driven outside existing footprint
Rarity	N/A		N/A
Representative	Intrusive		Little – restore original form

7. Conservation policies

The policies in this section provide for the care and management of the bridge to ensure its conservation as a State Heritage item. The policies provide for the retention and enhancement, through appropriate conservation and interpretation, of the heritage values of the bridge, its setting and its ongoing operations.

The OCMP contains policies designed to guide and manage the entire population of timber truss bridges to be retained by Transport for NSW. These general polices identify the broader principles and practices that are to be undertaken and may not specifically apply to an individual bridge. For clarity these policies have been omitted from this bridge specific CMP. Policies from the OCMP that apply to this bridge (Policies 1–10) and additional policies relating to significant elements (Policies 11–20) are included here.

7.1 Best practice in heritage management

The policies in this CMP provide for the care and management of the bridge to ensure its conservation as a State Heritage item. The policies provide for the retention and enhancement, through appropriate conservation and interpretation, of the heritage values of the bridge including its setting and ongoing use.

Policy 1: Retention of the cultural significance of the bridge

a) The bridge is a place of exceptional cultural significance and will be maintained and conserved in such a way which protects or enhances its cultural significance.

b) Conservation of the bridge will accord with the definitions and principles of The Burra Charter: the Australia ICOMOS Charter for Places of Cultural Significance and include all significant components and attributes of the place and its setting.

c) All current and future owners, managers and consent authorities responsible for the management of the bridge and/or its setting will be jointly responsible for the conservation of the significance of the bridge.

d) The conservation management of the bridge will be undertaken in consultation with heritage practitioners with relevant expertise and experience working in collaboration with structural engineers with relevant expertise and experience as required.

Policy 2: Adoption, implementation and review of the CMP

a) The conservation policies set out in this document will be formally adopted by Transport for NSW as a guide to future conservation and development of the bridge.

b) Transport for NSW will make resources available for the implementation of these polices during any works to the bridge or its setting, including routine maintenance.

c) Transport for NSW will ensure this document is both available for, and understood by staff coordinating and undertaking the ongoing maintenance of the bridge.

d) This CMP will be made available to the public. Copies will be lodged with all relevant administrative, maintenance, heritage and archival bodies/agencies, as well as being held by Transport for NSW and be readily available for public reference.

e) This CMP will be reviewed every five years to incorporate changes in conservation methodology or practice, changes in legislation or user requirements, and any new historical evidence that comes to light. The effectiveness of conservation treatments will also be considered and if required, corrective action recommended. The reviewed CMP will be submitted to the Heritage Council for endorsement.

7.2 Ensuring bridges have a role and use in life of communities

The continued use of the bridge as a functioning crossing for vehicles is integral to its cultural significance and survival. New work will be required to adapt the bridge to changing transportation needs.

Policy 3: Use of the bridge

a) Transport for NSW will continue to engage with local communities to ensure that the bridge is retained and managed in a way that meets community needs.

b) The bridge will be used for vehicular traffic. The continued use of this bridge as a functioning crossing for general access vehicles is integral to its cultural significance.

c) Unacceptable uses of the bridge include any uses or activities that may cause or accelerate damage to the fabric or to the views to and from the bridge (e.g. utilities).

d) Transport for NSW will consider arranging for the removal and relocation of existing utilities from the bridge if possible and if opportunity arises.

Policy 4: Maintenance and repair

The timber in timber truss bridges is generally not original fabric. The removal of deteriorated timber and its replacement with new timber fabric of suitable species is essential for the conservation of the bridge.

a) Ongoing repair and maintenance will be carried out to ensure that the minimum standards of maintenance under the *Heritage Act 1977* are met, and that each significant element in the bridge retains its level of significance. Works will be undertaken by suitably skilled workers with proven expertise in the relevant field and under adequate supervision.

b) Transport for NSW will prepare an Incident Response Plan for the bridge to minimise the risk and duration of emergency works, and manage such works so that the public and the bridge is kept safe, and so that works do not impact significant fabric.

c) The bridge is located on a public road and must not create a public safety hazard, but will be maintained both to support its ongoing functionality and its significant form.

d) The bridge will be regularly inspected by specialists for the integrity of the structure. Any issues affecting public safety, if found, will be addressed by appropriate methods.

e) A separate specialist will be engaged twice a year to inspect for and treat any termites.

f) In order to carry out maintenance and repair work safely, various support structures may be necessary including Bailey bridge (or equivalent), temporary props and access scaffolding. These structures are temporary in nature, and will be removed when no longer required.

Policy 5: New work

New work will be required to adapt the bridge to changing transportation needs. The endorsed Strategy and OCMP acknowledged the need to use modern materials to ensure the bridges have sufficient strength and safety for modern vehicles. These policies aim to ensure that new works and new materials are not damaging to heritage significance, but are comparable with the old in quality and do not dominate the trusses in bulk, scale or character. Appropriate design using modern materials and techniques can be an effective way of distinguishing new work from original if it is used with care and design excellence.

a) Elements of the bridge will be conserved in accordance with their level of significance.

b) The bridge will continue to carry traffic appropriate to its place in the road network. The bridge may be adapted to ensure its continued serviceability provided this does not compromise its heritage significance. Subject to relevant approvals, this may include introducing new materials to meet load, safety and durability requirements.

c) Transport for NSW will match the excellence of the originals in the quality of design and construction of any modifications or new works.

d) For works not covered by Standard or Specific Exemptions or by exemptions identified in an endorsed bridge specific CMP, applications to the Heritage Council for approval for specific works will be submitted, accompanied by a statement of heritage impact (SOHI) and, if required, the relevant statutory application under the *Heritage Act 1977*. The approval and decision making process for structural upgrades is given on the following page.

Figure 7-1: Approval process for structural upgrades and new work.

INDENTIFY	• Identify and justify need for upgrade works • Determine bridge heritage listings status (SHR/S170/LEP)
APPROVAL PATHWAY	• Determine required approval pathway • Obtain advice from environment / heritage manager
SCOPE WORKS	• Consult this CMP and develop scope of works in collaboration with Environment, Bridge Engineering, Bridge Maintenance Planner, Bridge Works Manager, Community Stakeholder & Engagement Section and Transport for NSW Heritage Specialist
CONCEPT DESIGN	• Develop heritage concept options and heritage concept sketches in collaboration with OEH as well as Environment, Bridge Engineering, Bridge Maintenance Planner, Bridge Works Manager, Community Stakeholder & Engagement Section and Transport for NSW Heritage Specialist
IMPACT ASSESSMENT	• Prepare Statement of Heritage Impact (SOHI) • Undertake internal and external review of SOHI
S60 APPLICATION	• Prepare and submit S60 application to OEH • Respond to any inquiries or requests for more information
APPROVAL	• Receive works approval notification or review application if not approved • Review conditions of approval and incorporate into works program
COMPLETE WORKS	• Undertake works in accordance with any conditions of approval
UPDATE DATA	• Update heritage registers and inform OEH • Update relevant internal systems, databases or documents.

Source: Adapted from Roads and Maritime, NSW Timber Truss Road Bridges, Overarching CMP,February 2018, p 36.

7.3 Interpretation and appreciation of timber truss bridges

There are some misconceptions with regard to heritage timber truss road bridges (e.g. they are inherently too weak for modern vehicles, they are inherently unsafe, they are inherently noisy, heritage listing inherently prohibits any change). This not only means that the bridges are not fully appreciated, but it can also lead to local communities lobbying for a new concrete bridge, often wishing to conserve the timber bridge off line only when it is too late. Accurate, interesting and relevant interpretive material is critical for assisting local communities to appreciate their bridge, which will then assist with conservation.

Policy 6: Interpretation

a) The heritage significance of the bridge will be communicated through effective heritage interpretation.

b) Interpretation will be based on the historical themes and analyses documented in this CMP.

c) Interpretation will conform to the Heritage Division's Interpreting Heritage Places and Items Guidelines and with Transport for NSW's Heritage Interpretation Guideline.[138]

Policy 7: Protection and enhancement of visual setting

a) Any development proposed for the land adjacent to the bridge, whether inside or outside the curtilage, should be considered carefully to ensure that it does not have an unacceptable visual impact which could cause a reduction in the aesthetic significance of the bridge.

b) Signage in the vicinity of the bridge should be minimised to what is necessary for safety and identification so that it does not create visual clutter and block views.

c) Vegetation in the vicinity of the bridge should be kept to a minimum. Weeds should be removed, and vegetation clearance should be regularly undertaken with a view to improving the visual setting, and to reduce the risk of fire by creating a cleared area that acts as a fire break.

d) Any relevant planning and statutory controls must be adhered to when considering development or works adjacent to the bridge.

7.4 Documentation and approvals

Well managed records are important as they enhance the understanding of the heritage item, its significance and the impact of change as part of the conservation and management process.

Policy 8: Archival recording

a) The records created by Transport for NSW relating to the bridge are recognised as an integral part of the heritage portfolio. They will be managed to ensure permanent retention as State records, but must also be made available so that they can be readily accessed by relevant stakeholders where required.

[138] NSW Heritage Office, Heritage Information Series, Interpreting Heritage Places and Items Guidelines, 2005; NSW Roads and Maritime, Heritage Interpretation Guideline, Draft February 2016.

b) Immediately before, during and after any works being undertaken on the bridge, an inspection will be completed, detailing and photographing the condition and defects of all elements.

c) A complete archival recording will be undertaken of the bridge including 3D mapping (laser scanning).

d) All methods and materials used during any work done to the bridge will be fully documented with written information and appropriate photographs. Records, reports and photographs of any work carried out on the bridge will be placed in a permanent archive to enable retrieval of information afterwards.

e) A representative sample of any original fabric assessed to be of heritage significance (such as cast iron shoes), but to be removed from the bridge will be suitably archived and recorded on the Transport for NSW Section 170 Heritage and Conservation Register unless similar samples are already archived. This will include:

  - Two top chord shoes
  - Two tear drop shaped shoes
  - Two of each of the three types of wrought iron washers

Policy 9: Archaeology

a) Transport for NSW will consult with relevant Aboriginal stakeholders about any proposed project or works that may impact on areas of Aboriginal archaeological potential or cultural significance. Wherever harm to Aboriginal relics is considered likely in the course of works, an AHIP shall be obtained, in accordance with Section 90(1) of the NPW Act 1974.

b) Any subsurface disturbance of land that may have archaeological potential will be carried out in accordance with the Transport for NSW Cultural Heritage Guidelines and the archaeological provisions of the Heritage Act 1977. A Due Diligence Assessment will be provided for any works which disturb the land outside of an AHIP area (including, cutting, filling, ground penetration, stockpiles, mounds, etc). The Assessment shall be in accordance with the Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales (DECCW 2010).

c) The Transport for NSW Unexpected Heritage Items Heritage Procedure (current edition 02, November 2015), must be followed to manage the discovery of all unexpected heritage items (both Aboriginal and non-Aboriginal) that are discovered during Transport for NSW activities.

Policy 10 – Exemptions and approvals

ENDORSED
CONSERVATION MANAGEMENT PLAN
Heritage Council of New South Wales
Date endorsed 18/12/2020
OEH/HC File DOC20/396610

a) Routine maintenance works identified in Table 1 of Appendix A can proceed without requiring notification to the Heritage Council.

b) Works identified in Table 2 of Appendix A will need approval / consent advice sought regarding the nature/type of approval required prior to works being planned.

7.5 Additional policies for significant elements

Policies related to fabric use words specifically defined in the Burra Charter as follows:

> ***Fabric*** *means all the physical material of the place including elements, fixtures, contents and objects.*
>
> ***Conservation*** *means all the processes of looking after a place so as to retain its cultural significance.*
>
> ***Preservation*** *means maintaining a place in its existing state and retarding deterioration.*
>
> ***Restoration*** *means returning a place to a known earlier state by removing accretions or by reassembling existing elements without the introduction of new material.*
>
> ***Reconstruction*** *means returning a place to a known earlier state and is distinguished from restoration by the introduction of new material.*
>
> ***Adaptation*** *means changing a place to suit the existing use or a proposed use.*
>
> ***Interpretation*** *means all the ways of presenting the cultural significance of a place.*

7.5.1 Policy 11 – Truss span top chords and principals (exceptional significance)

The timber fabric is not original and is subject to deterioration from rot and termite attack.

a) Truss span top chords and principals should be reconstructed to their original design dimensions and detailing using NSW Hardwood of suitable strength and durability.

b) The timber of the top chords and principals, once reconstructed, should be preserved for as long as practical by ensuring that the protective coating (breathable white paint) is reapplied as necessary and that termite inspections and treatments are undertaken regularly.

c) They should be replaced before deterioration affects safety or serviceability of the bridge.

7.5.2 Policy 12 – Bottom chords and butting blocks (currently intrusive)

The timber fabric is not original and is subject to deterioration from rot and termite attack. The original design is not capable of carrying current vehicular loads and requires some adaptation which is visually recessive and allows all the original details of the bottom chord to be understood.

a) Truss span bottom chords and butting blocks should be reconstructed to their original design dimensions and detailing using NSW Hardwood of suitable strength and durability, with suitably designed strengthening provided to allow the bridge to carry modern vehicles. External steel plates have been determined to be the most appropriate option in this case.

b) The timber of the bottom chords and butting blocks, once reconstructed, should be preserved for as long as is practical by ensuring that the protective coating (breathable white paint) is reapplied as necessary and that termite inspections and treatments are undertaken regularly, and that the bolts in the bottom chord are kept tight.

c) They should be replaced before deterioration affects safety or serviceability of the bridge.

7.5.3 Policy 13 – Diagonals and props (high significance)

The timber fabric is not original and is subject to deterioration from rot and termite attack.

a) Truss span diagonals and props should be reconstructed to their original design dimensions and detailing using NSW Hardwood of suitable strength and durability.

b) The timber of the diagonals and props, once reconstructed, should be preserved for as long as is practical by ensuring that the protective coating (breathable white paint) is reapplied as necessary and that termite inspections and treatments are undertaken regularly.

c) They should be replaced before deterioration affects safety or serviceability of the bridge.

7.5.4 Policy 14 – Truss span metal (high significance)

Some of the truss span metal is original fabric, but in poor condition and modified and subject to sudden brittle failure. There is sufficient evidence of the original to inform reconstruction.

a) Truss span metal components should be reconstructed to their original design dimensions and detailing with new metal components. Tension rods require some adaptation and should be reconstructed at larger dimensions to allow the bridge to carry modern vehicles.

7.5.5 Policy 15 – Truss span sway braces (currently intrusive)

None of the original form, fabric or function of the sway braces remains in 2017. The sway braces present in 2017 are also ineffectual and should not be conserved or reconstructed. The original design cannot be effectively reconstructed due to the excessive shrinkage of timbers available. Some adaptation is required to allow the bridge to function but also to interpret the original.

a) Truss span sway braces should be replaced with new sway braces which reflect the form and function of the original. The new sway braces should be painted white to restore the original aesthetic to the bridge and to indicate that the original sway braces were timber.

7.5.6 Policy 16 – Truss span cross girders (little significance)

The timber fabric is not original and is subject to deterioration from rot and termite attack. The original design of the primary cross girders cannot be effectively reconstructed due to the excessive shrinkage of timbers available affecting the ability of the truss to carry any loads. Some adaptation is required to allow the bridge to function but also to interpret the original.

a) Truss span secondary cross girders should be reconstructed to their original design dimensions and detailing using NSW Hardwood of suitable strength and durability.

b) Truss span primary cross girders should be replaced with new steel primary cross girders which reflect the form and function of the original. The new steel primary cross girders should be painted white to restore the original aesthetic to the bridge and also to indicate as a form of interpretation that the original primary cross girders were timber.

7.5.7 Policy 17 – Approach spans (little significance)

The approach spans do not contribute directly to the significance of the item (the general configuration is common, neither the current detailing nor the fabric is original). The current configuration is not representative of the pre-1893 approach spans, and confuses interpretation. It is not feasible to restore the original design, as the timber approach spans are not sufficiently strong to support a complying traffic barrier, and so cannot meet legislative safety requirements.

a) The approach spans should be adapted to allow for modern loading and provision of safe traffic barrier. Modifications to the approach spans should be done is such ways that the truss spans remain visually dominant, guided by Burra Charter principals for new work.

7.5.8 Policy 18 – Decking (currently intrusive)

The decking does not contribute directly to the significance of the item, and the current decking is intrusive because modifications are so substantial that these elements are now damaging to the item's heritage significance, causing structural deficiencies and undermining interpretation.

a) The decking should be replaced with new decking which should reflect the fabric and function of the original and should restore the original aesthetic of the bridge.

b) The decking including its wearing surface should be maintained in such a way to ensure the safety of vehicles travelling across the bridge to reduce the risk of damage to the bridge.

7.5.9 Policy 19 – Railing (little significance)

The railing does not contribute directly to the significance of the item, and does not have any ability to prevent a vehicle from falling off the bridge. The railings are therefore a safety hazard.

a) The railing should be replaced with a new visually recessive but complying traffic barrier.

7.5.10 Policy 20 – Piers and abutments (little significance)

The piers and abutments do not contribute directly to the significance of the item. Neither the current detailing nor the fabric is original, and it is not physically possible to reconstruct the original.

a) The piers should be replaced with new piers which reflect the form and function of the original. The new piers should be dark grey or brown to restore the original aesthetic.

b) The abutments should be replaced with new abutments designed to be visually recessive.

8. Implementation of CMP

The conservation policies in Section 7 provide for the ongoing care and management of the bridge so as to ensure the conservation of its cultural heritage values. Critical actions with regard to this bridge for the implementation of this CMP and the Overarching CMP are identified and scheduled in the table below.

Year	Action by Transport for NSW	Priority
Year 1	Submit CMP to the Heritage Council for endorsement.	High
	Formally adopt this CMP and integrate with all other documentation, planning and management processes relating to the bridge.	High
	Train relevant Transport for NSW stakeholders in the use of this CMP.	Medium
	Prepare an Incident Response Plan for the bridge.	Medium
	Continue to actively conserve the bridge by appropriate maintenance, repair and management.	High
	Continue to engage with communities to ensure that the bridge is managed in such a way that meets community needs.	High
	Where modifications are required to the bridge to meet community needs, follow process set out in flowchart provided in Figure 7-1.	High
Years 2-4	Continue to actively conserve the bridge by appropriate maintenance, repair and management.	High
	Continue to engage with communities to ensure that the bridge is managed in such a way that meets community needs.	High
	Where modifications are required to the bridge to meet community needs, follow process set out in flowchart provided in Figure 7-1.	High
Year 5	Continue to actively conserve the bridge by appropriate maintenance, repair and management.	High
	Continue to engage with communities to ensure that the bridge is managed in such a way that meets community needs.	High
	Where modifications are required to the bridge to meet community needs, follow process set out in flowchart provided in Figure 7-1.	High
	Review this CMP.	Medium

9. References

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10. Abbreviations and Terminology

Term / Acronym	Description
BIS	Roads and Maritime's Bridge Information System
CMP	Conservation management plan
DMR	NSW Department of Main Roads (now Roads and Maritime)
FRP	Fibre Reinforced Polymer
Heritage Act	*Heritage Act 1977* (NSW)
LALC	Local Aboriginal Land Council
LEP	Local Environmental Plan. A type of planning instrument made under Part 3 of the *Environmental Planning and Assessment Act 1979* (NSW)
LVL	Laminated Veneer Lumber (an engineered wood product)
MRB	Main Roads Board (now Roads and Maritime)
NAASRA	National Association of Australian State Road Authorities
OEH	Heritage Division of the Office of Environment and Heritage (now Heritage NSW)
PACHCI	Roads and Maritime Procedure for Aboriginal Cultural Heritage Consultation and Investigation
PAD	Potential Archaeological Deposit
PWD	Department of Public Works (now Roads and Maritime)
REF	Review of Environmental Factors
Roads and Maritime	NSW Roads and Maritime Services
RTA	NSW Roads and Traffic Authority (now Roads and Maritime)
SHR	State Heritage Register
SOHI	Statement of heritage impacts
WHS	Work Health and Safety

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Appendix A

Schedule of Conservation Works

Table A-1: Works exempt under s57 of the Act not requiring notification to the Heritage Council

Element	Works
Site and general	Removal of any rubbish or debris from the site
	Vegetation clearance required to maintain an Asset Protection Zone in accordance with the recommendations of a suitably qualified Bushfire Assessment Consultant accredited by the Fire Protection Association Australia (FPA Australia).
Timber elements generally	Remove any accumulations of dirt or fauna
	Inspect timber and treat active termites
	Check for paint damage, clean and repaint as necessary
	Tighten all bolts
Timber decking	Reseal decking if required
Timber railings	Check for incident damage, repair as necessary to existing detail

Table A-2: Works that may require Heritage Council approval/consent under s57or s60 of the Act

Elements	Description	Condition / Integrity	Significance (State)	Conservation Works
Truss span top chords and principals	Timber top chords and principals are in very poor condition. Dimensions (length as well as cross-section) are not original. Some principals have been spliced, with the introduction of intrusive metal components. These modifications have impacted significance and reduced the capacity of the bridge to carry loads.	Poor / Fair	Exceptional	Replace all top chords and principals with new NSW hardwood timber members of original dimensions and paint white (original colour).
Truss span bottom chords and butting blocks	Timber bottom chords are in very poor condition. Dimensions (length as well as cross-sections) are far from original. Intrusive metal splice plates have been introduced. These modifications reduce both capacity and significance. The original design of these elements has insufficient capacity for modern loads.	Poor / Poor	Intrusive	Replace all bottom chords and butting blocks with new NSW hardwood timber members of original dimensions strengthened with external steel plates so that all significant original details can still be viewed and understood. Both timber and external steel plate strengthening to be painted white.
Truss span diagonals and props	Timber diagonals and props are in very poor condition. Dimensions (length as well as cross-section) and detailing are not original. These modifications have impacted significance and reduced the capacity of the bridge to carry loads.	Poor / Fair	High	Replace all diagonals and props with new NSW hardwood timber members of original dimensions and detailing and paint white (original colour).
Truss span metal components	Cast iron shoes: Top chord shoes are original fabric but in poor condition and some are broken. Bottom chord shoes are modified, broken or not original.	Poor / Fair	Exceptional	Replace with new ductile cast iron shoes of original dimensions and detailing and paint black (original colour).
	Wrought iron tension rods: No original fabric, not original sizes, poor condition the original design of tension rods has insufficient capacity for modern loads.	Poor / Fair	Moderate	Replace with new steel tensions rods of enlarged cross-sectional dimensions to carry modern loads but other detailing as original and paint black.
	Wrought iron washer plates: Washer plates of all three types are original fabric but in poor condition and some have been modified due to tension rod changes.	Poor / Good	High	Replace with new steel washer plates of original dimensions and detailing, except larger holes for larger tension rods, and paint black (original colour).
	Wrought iron fish plates: These have been removed from the bottom chord	missing	High	Steel fish plates of original dimensions and detailing should be reinstated at original locations as a distinguishing feature of the Old PWD truss.
Truss span sway braces	Sway braces are not original in form, fabric or function. The current sway braces reduce both capacity and significance. The original design of these elements has insufficient capacity for modern loads and cannot accommodate shrinkage.	Poor / Poor	Intrusive	Replace all sway braces with new steel sway braces designed to reflect the original form and function and able to carry modern loads. Paint white.
Truss span cross girders	Timber cross girders are in very poor condition and original detailing and load paths have been lost. Intrusive metal components have been introduced to extend the length of some primary cross girders. These modifications have impacted significance and reduced the capacity of the bridge to carry loads. The original design cannot be reinstated due to shrinkage of available timbers.	Poor / Poor	Little	Replace all secondary cross girders with new NSW hardwood timber members of original dimensions and detailing. Replace all primary cross girders with new steel cross girders of original dimensions and detailing.
Approach spans	Approach spans are in poor condition. Original design has insufficient capacity for modern loads and cannot accommodate a complying traffic barrier.	Poor / Poor	Little	Replace approach spans with steel girder approach spans of shorter lengths (3 of equal length) to minimise the depth so they remain visually recessive.
Decking	Modifications are intrusive. Original design has insufficient capacity for modern loads and cannot be reconstructed due to shrinkage of available timbers.	Poor / Poor	Intrusive	Replace with stress laminated timber (SLT) deck throughout all spans.
Railing	Railings are in poor condition. Original design (and current) is a safety hazard.	Poor / Poor	Little	Replace with a visually recessive but complying steel traffic barrier system.
Piers and abutments	Piers and abutments are in poor condition and modifications have substantially weakened their resistance to flood loads as well as reducing significance.	Poor / Poor	Little	Replace abutments with concrete abutments and replace piers with steel piers which accurately reflect the original form and function of the piers.
Visual setting and context	Bridge is closed to traffic and site is overgrown with vegetation	Poor / Poor	Moderate	Open bridge to traffic (after all abovementioned works) and clear overgrown vegetation to restore appropriate sight distances and views of the bridge.

Schedule of Conservation Works

Elements	Description	Condition / Integrity	Significance (State)	Conservation Works
Truss span top chords and principals	Timber top chords and principals are in very poor condition. Dimensions (length as well as cross-section) are not original. Some principals have been spliced, with the introduction of intrusive metal components. These modifications have impacted significance and reduced the capacity of the bridge to carry loads.	Poor / Fair	Exceptional	Replace all top chords and principals with new NSW hardwood timber members of original dimensions and paint white (original colour).
Truss span bottom chords and butting blocks	Timber bottom chords are in very poor condition. Dimensions (length as well as cross-sections) are far from original. Intrusive metal splice plates have been introduced. These modifications reduce both capacity and significance. The original design of these elements has insufficient capacity for modern loads.	Poor / Poor	Intrusive	Replace all bottom chords and butting blocks with new NSW hardwood timber members of original dimensions strengthened with external steel plates so that all significant original details can still be viewed and understood. Both timber and external steel plate strengthening to be painted white.
Truss span diagonals and props	Timber diagonals and props are in very poor condition. Dimensions (length as well as cross-section) and detailing are not original. These modifications have impacted significance and reduced the capacity of the bridge to carry loads.	Poor / Fair	High	Replace all diagonals and props with new NSW hardwood timber members of original dimensions and detailing and paint white (original colour).
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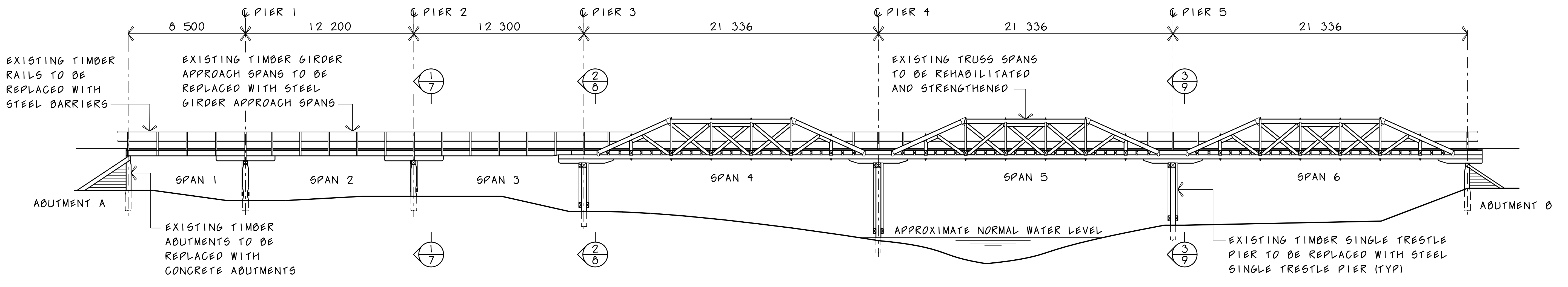
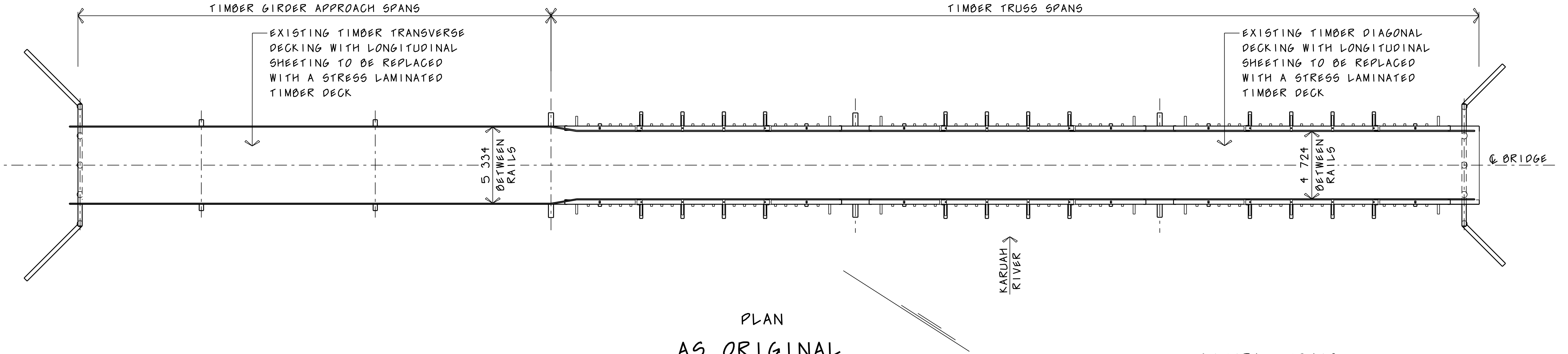
	Wrought iron washer plates: Washer plates of all three types are original fabric but in poor condition and some have been modified due to tension rod changes.	Poor / Good	High	Replace with new steel washer plates of original dimensions and detailing, except larger holes for larger tension rods, and paint black (original colour).
	Wrought iron fish plates: These have been removed from the bottom chord	missing	High	Steel fish plates of original dimensions and detailing should be reinstated at original locations as a distinguishing feature of the Old PWD truss.
Truss span sway braces	Sway braces are not original in form, fabric or function. The current sway braces reduce both capacity and significance. The original design of these elements has insufficient capacity for modern loads and cannot accommodate shrinkage.	Poor / Poor	Intrusive	Replace all sway braces with new steel sway braces designed to reflect the original form and function and able to carry modern loads. Paint white.
Truss span cross girders	Timber cross girders are in very poor condition and original detailing and load paths have been lost. Intrusive metal components have been introduced to extend the length of some primary cross girders. These modifications have impacted significance and reduced the capacity of the bridge to carry loads. The original design cannot be reinstated due to shrinkage of available timbers.	Poor / Poor	Little	Replace all secondary cross girders with new NSW hardwood timber members of original dimensions and detailing. Replace all primary cross girders with new steel cross girders of original dimensions and detailing.
Approach spans	Approach spans are in poor condition. Original design has insufficient capacity for modern loads and cannot accommodate a complying traffic barrier.	Poor / Poor	Little	Replace approach spans with steel girder approach spans of shorter lengths (3 of equal length) to minimise the depth so they remain visually recessive.
Decking	Modifications are intrusive. Original design has insufficient capacity for modern loads and cannot be reconstructed due to shrinkage of available timbers.	Poor / Poor	Intrusive	Replace with stress laminated timber (SLT) deck throughout all spans.
Railing	Railings are in poor condition. Original design (and current) is a safety hazard.	Poor / Poor	Little	Replace with a visually recessive but complying steel traffic barrier system.
Piers and abutments	Piers and abutments are in poor condition and modifications have substantially weakened their resistance to flood loads as well as reducing significance.	Poor / Poor	Little	Replace abutments with concrete abutments and replace piers with steel piers which accurately reflect the original form and function of the piers.
Visual setting and context	Bridge is closed to traffic and site is overgrown with vegetation	Poor / Poor	Moderate	Open bridge to traffic (after all abovementioned works) and clear overgrown vegetation to restore appropriate sight distances and views of the bridge.



ELEVATION



PLAN

AS ORIGINAL

ORIGINAL DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE.
DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:

- EXISTING TRUSS GEOMETRY IS DISTORTED
- EXISTING CROSS GIRDERS ARE IRREGULAR AND GENERALLY LONGER THAN ORIGINAL
- ORIGINAL DECK HAS BEEN REPLACED WITH SPACED DECKING OVERLAID WITH LONGITUDINAL SHEETING
- KERBS HAVE BEEN ADDED ON ALL SPANS
- EXISTING BRIDGE IS PROPPED WITH VARIOUS TEMPORARY MEASURES

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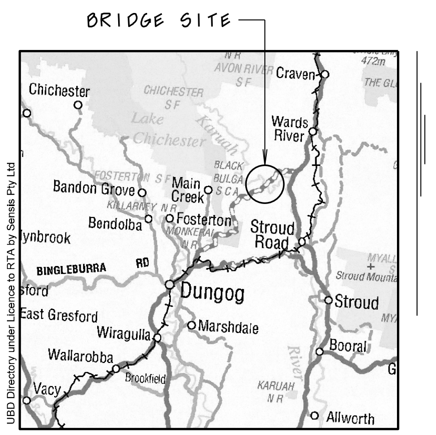

LOCALITY PLAN

THE BRIDGE SITE IS APPROXIMATELY 235 KM BY ROAD FROM SYDNEY

GENERAL NOTES

SCALE 0 2.5 5.0 7.5m

DIMENSIONS ARE IN MILLIMETRES.
DIMENSIONS HAVE BEEN ADOPTED FROM THE ORIGINAL BRIDGE DRAWINGS (1881), REGISTRATION NUMBER OF PLANS: 0101 410 BC 0107.

ISSUE	DATE	REVISION	PREP	CHECK	AUTH
B	22.06.2017	CHANGE PROPOSED PIERS TO STEEL	JP	AN/SC	SD

UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT

GENERAL ARRANGEMENT - AS ORIGINAL

NSW GOVERNMENT Transport Roads & Maritime Services

PREPARED BY
BRIDGE AND STRUCTURAL ENGINEERING BRANCH
110 GEORGE STREET PARRAMATTA NSW 2150
PHONE (02) 8837-0832 FACSIMILE (02) 8837-0023

CLIENT:
HUNTER REGIONAL OFFICE
59 DARBY STREET NEWCASTLE
PHONE (02) 4924-0357 FACSIMILE (02) 4924-0301

	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 1 OF 9 — ISSUE B

CAD No KA897HGAA_B.dgn

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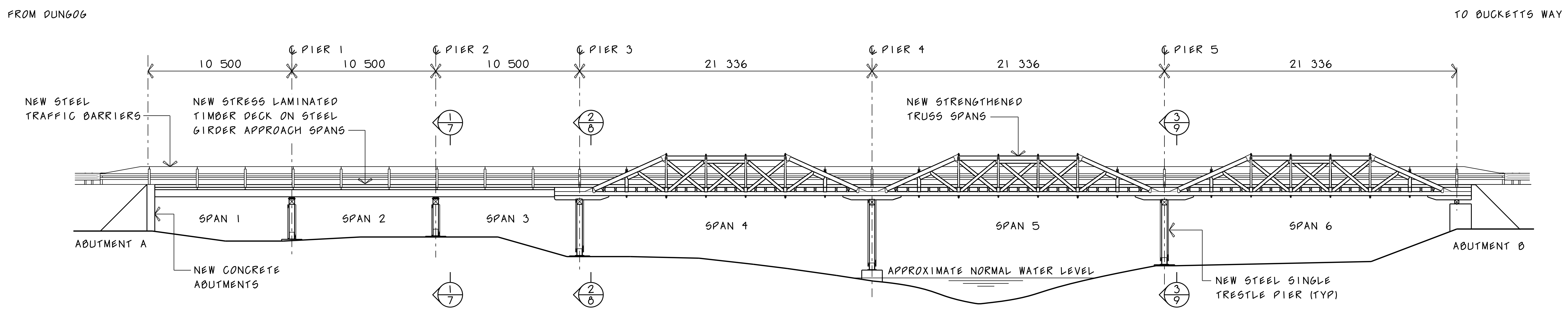
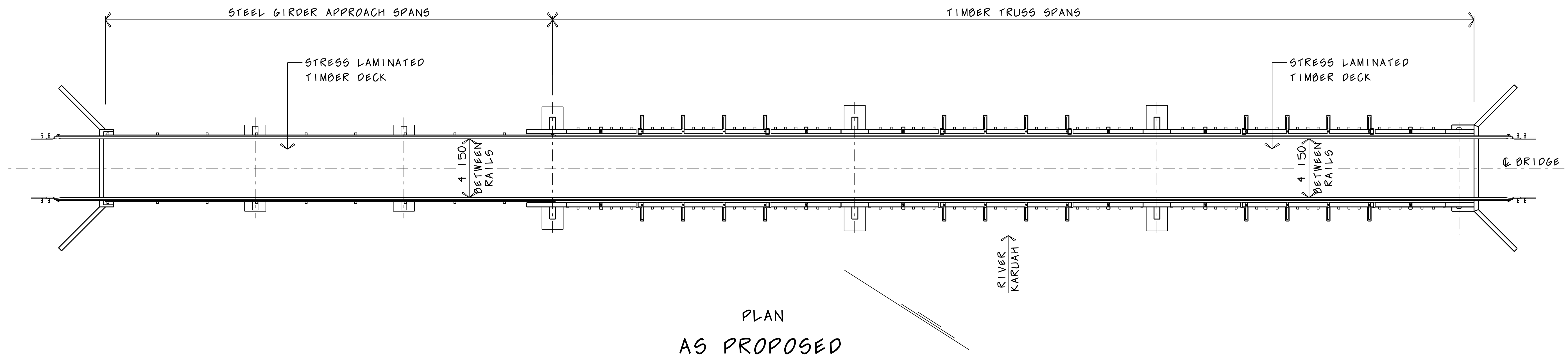


ELEVATION



PLAN

AS PROPOSED

GENERAL NOTES

SCALE 2.5 1.25 0 2.5 5.0 7.5m

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

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ISSUE	DATE	REVISION	PREP	CHECK	AUTH
B	22.06.2017	CHANGE PROPOSED PIERS TO STEEL	JP	AN/SC	SD

UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT
GENERAL ARRANGEMENT - AS PROPOSED

NSW GOVERNMENT — Transport Roads & Maritime Services

PREPARED BY
BRIDGE AND STRUCTURAL ENGINEERING BRANCH
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CLIENT:
HUNTER REGIONAL OFFICE
59 DARBY STREET NEWCASTLE
PHONE (02) 4924-0357 FACSIMILE (02) 4924-0301

	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 2 OF 9 — ISSUE B

CAD No KA897HGAB_B.dgn

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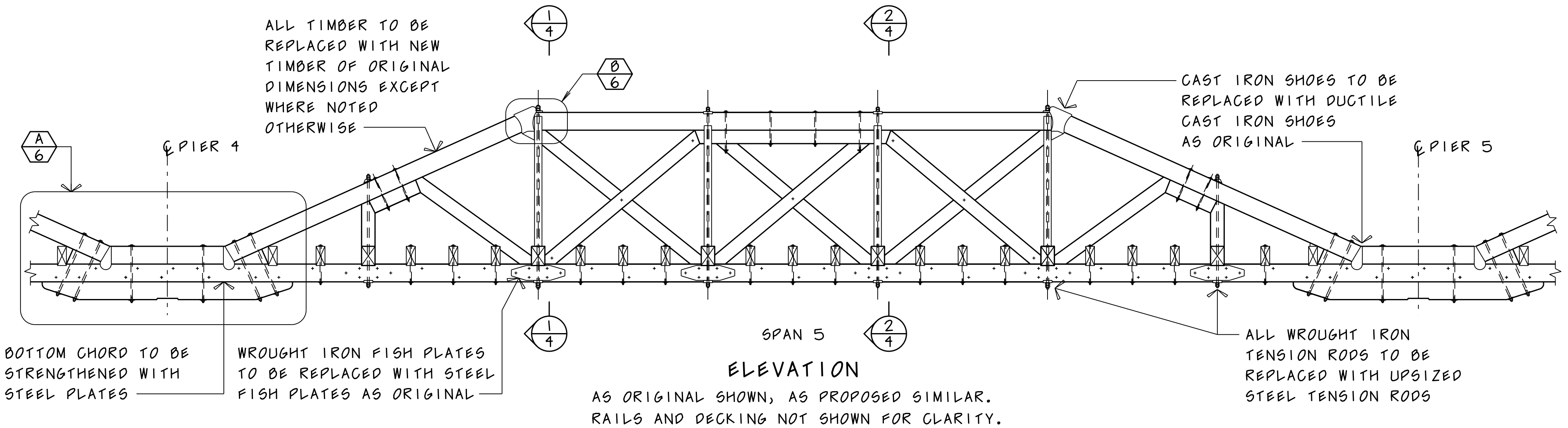

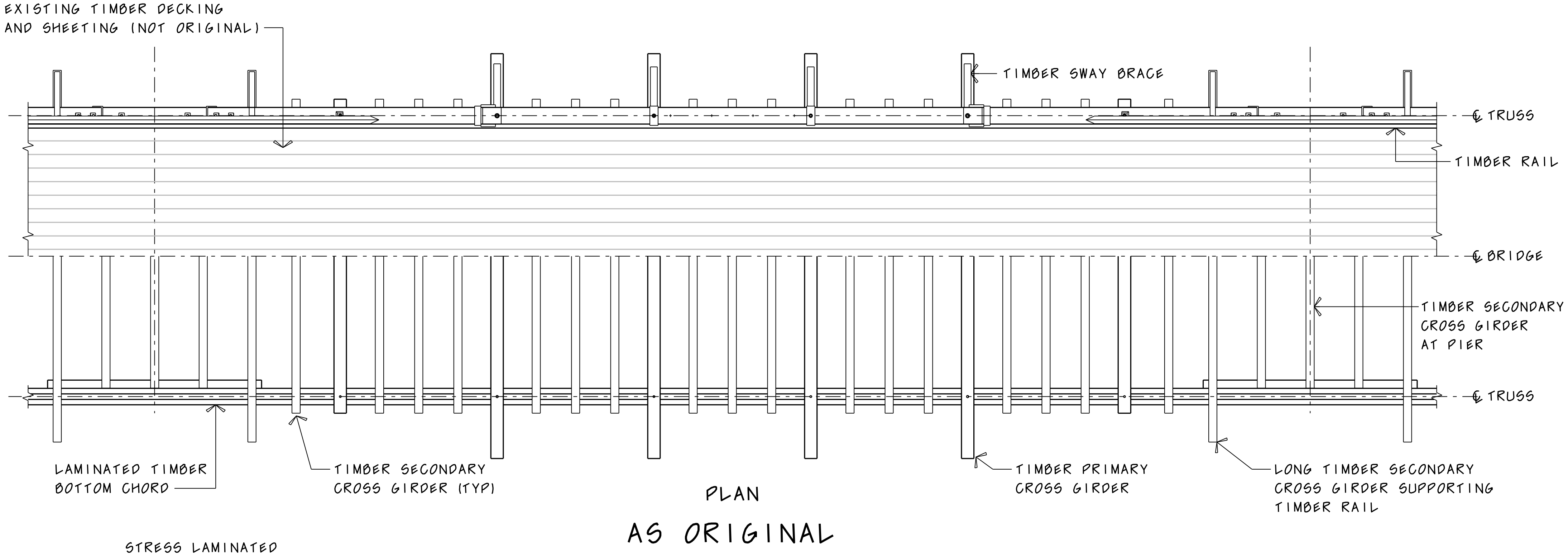

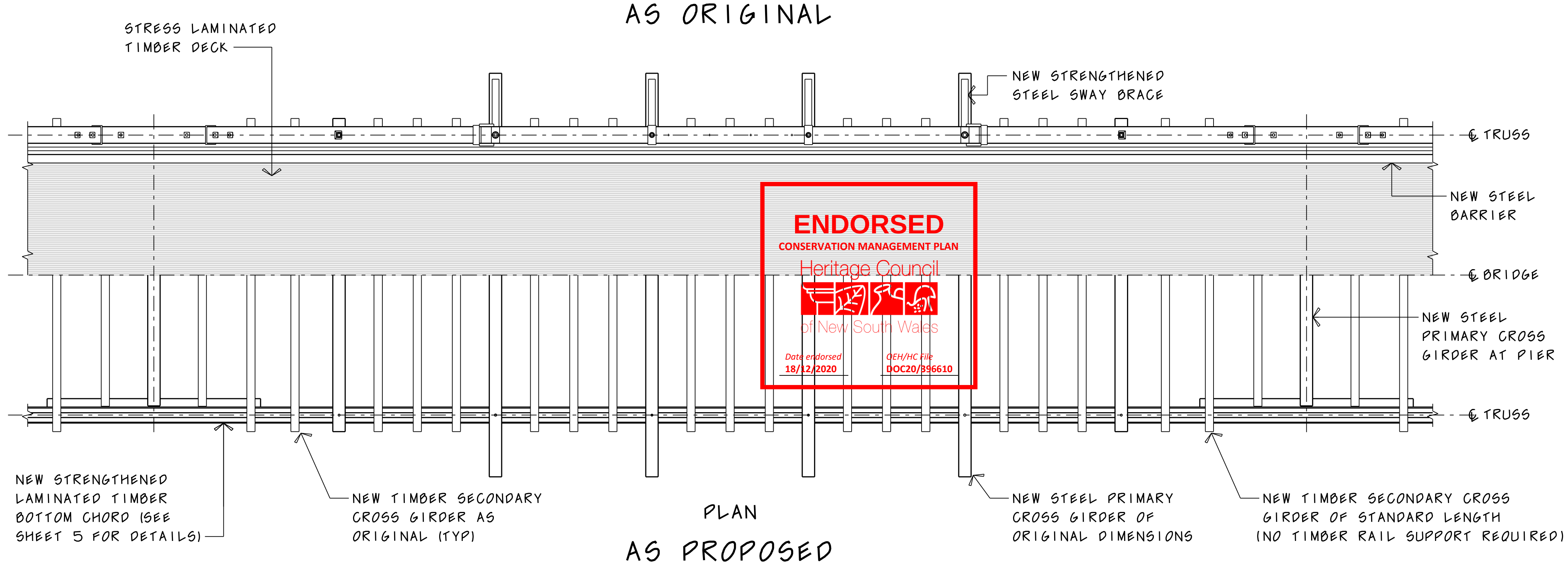

GENERAL NOTES

SCALE 1 000 500 0 1 000 2 000 3 000mm

ORIGINAL DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE. DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:

- EXISTING TRUSS GEOMETRY IS DISTORTED
- EXISTING CROSS GIRDERS ARE IRREGULAR AND GENERALLY LONGER THAN ORIGINAL
- ORIGINAL DECK HAS BEEN REPLACED WITH SPACED DIAGONAL DECKING OVERLAID WITH LONGITUDINAL SHEETING
- SOME TRUSS TIMBERS HAVE BEEN SPLICED
- SOME CAST IRON SHOES ARE BROKEN AND SOME HAVE BEEN REPLACED WITH STEEL
- ORIGINAL FISH PLATES HAVE BEEN REPLACED WITH STEEL PLATES OF DIFFERENT SHAPES AND SIZES
- ORIGINAL TIMBER SWAY BRACES HAVE BEEN REPLACED WITH STEEL SWAY BRACES OF DIFFERENT DIMENSIONS

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

ISSUE	DATE	REVISION	PREP	CHECK	AUTH

UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT
TRUSS SPANS - SHEET A

NSW GOVERNMENT — Transport Roads & Maritime Services

PREPARED BY: BRIDGE AND STRUCTURAL ENGINEERING BRANCH, 110 GEORGE STREET PARRAMATTA NSW 2150, PHONE (02) 8837-0832 FACSIMILE (02) 8837-0023

CLIENT: HUNTER REGIONAL OFFICE, 59 DARBY STREET NEWCASTLE, PHONE (02) 4924-0357 FACSIMILE (02) 4924-0301

	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016 — BRIDGE ENGINEER (REHABILITATION DESIGN)

SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 3 OF 9 — ISSUE A

CAD No KA897HTSA_SP.dgn

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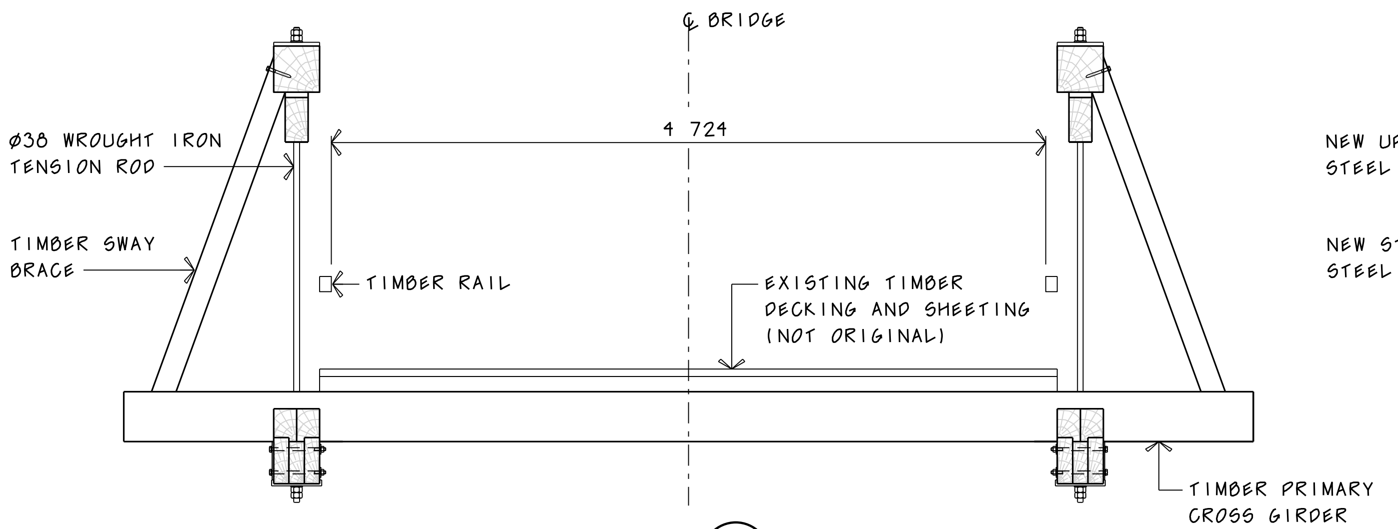
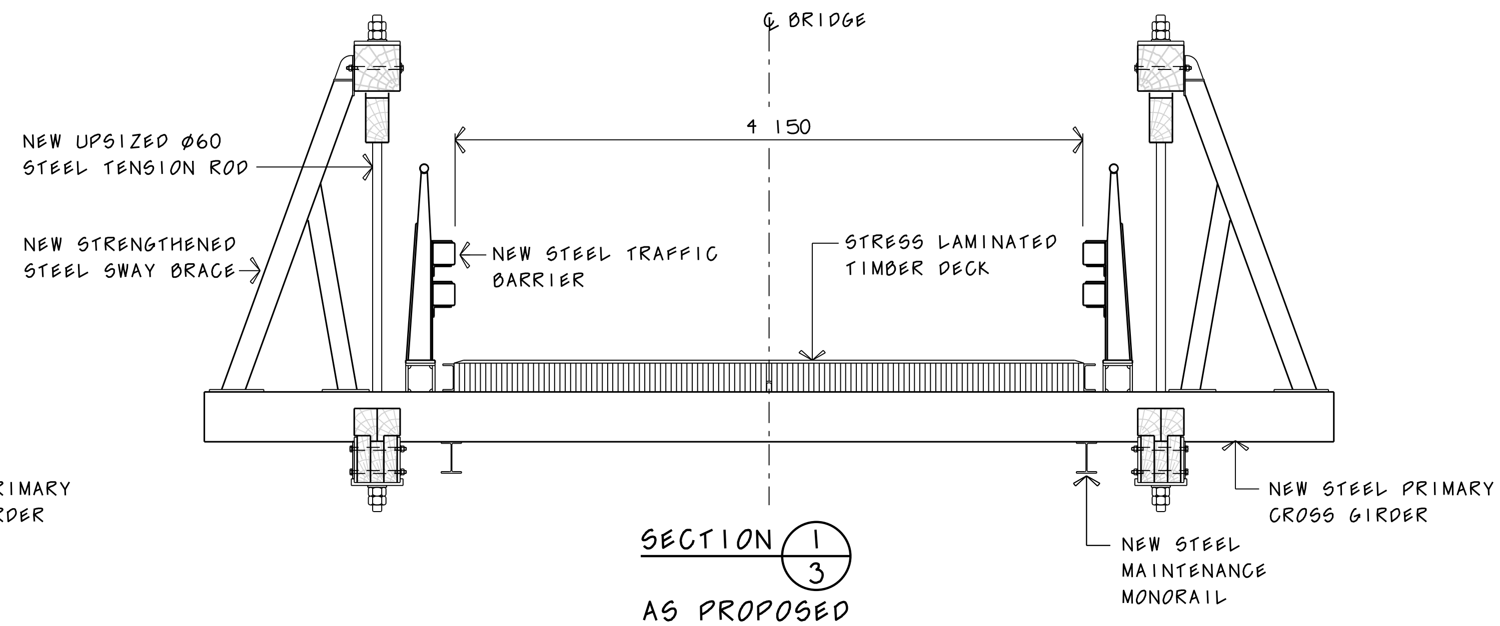
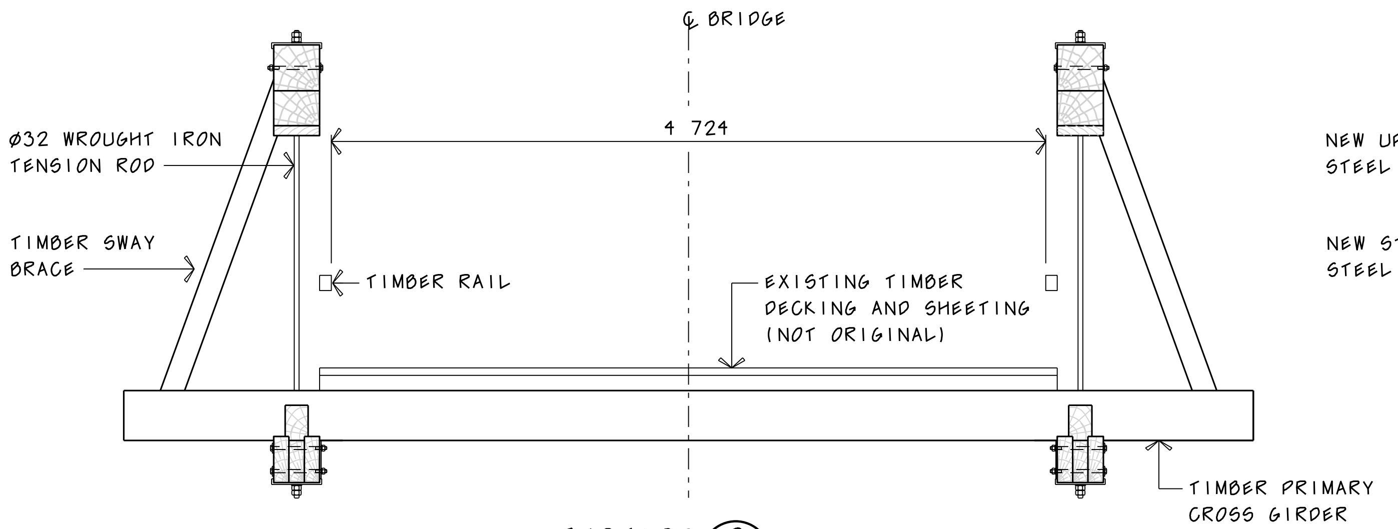


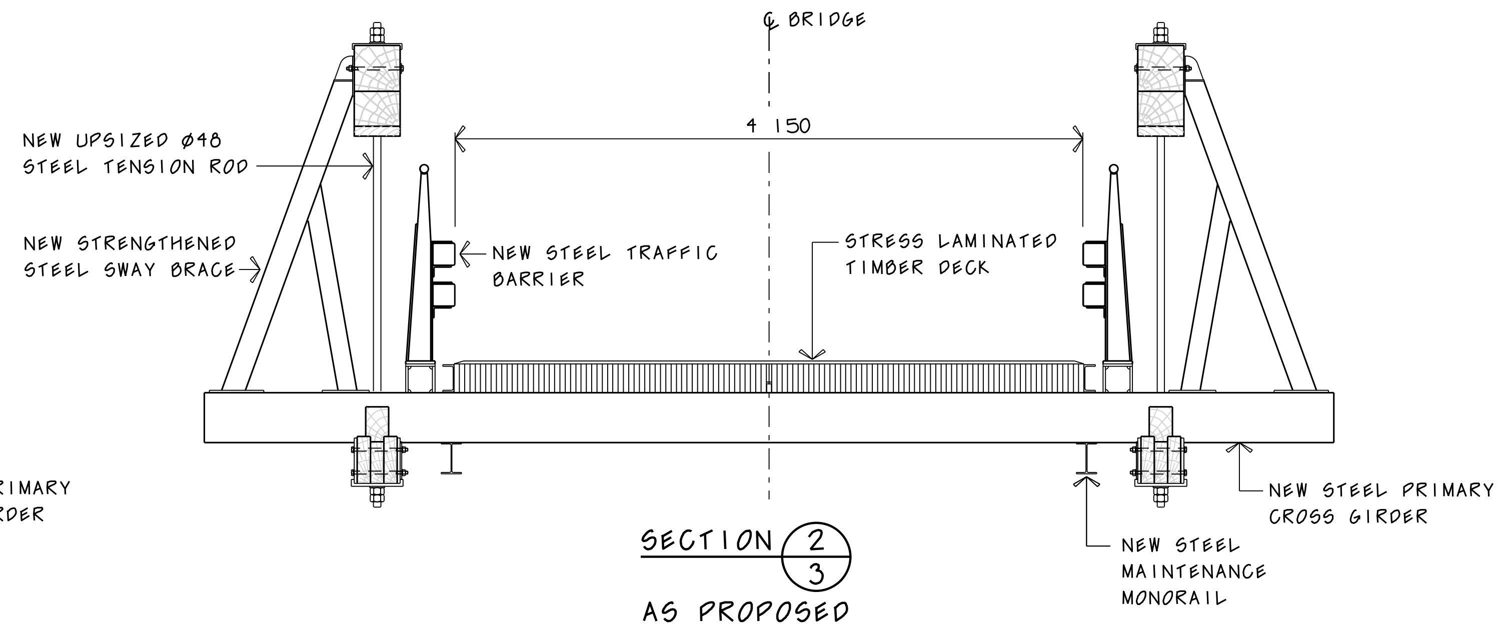
SECTION 1/3
AS ORIGINAL



SECTION 1/3
AS PROPOSED



SECTION 2/3
AS ORIGINAL



SECTION 2/3
AS PROPOSED

ENDORSED
CONSERVATION MANAGEMENT PLAN
Heritage Council of New South Wales
Date endorsed 18/12/2020
OEH/HC File DOC20/396610

GENERAL NOTES

SCALE 500 250 0 500 1 000 1 500mm

[illegible] DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE.
DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:
- EXISTING CROSS GIRDERS ARE IRREGULAR AND GENERALLY LONGER THAN ORIGINAL
- ORIGINAL DECK HAS BEEN REPLACED WITH SPACED DIAGONAL DECKING OVERLAID WITH LONGITUDINAL SHEETING
- ORIGINAL TIMBER SWAY BRACES HAVE BEEN REPLACED WITH STEEL SWAY BRACES OF DIFFERENT DIMENSIONS
- KERBS HAVE BEEN ADDED ON ALL SPANS
- ORIGINAL TENSION RODS HAVE BEEN REPLACED WITH STEEL TENSION RODS WITH INCREASED DIAMETER

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

ISSUE	DATE	REVISION	PREP	CHECK	AUTH

UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT
TRUSS SPANS - SHEET B

NSW GOVERNMENT | Transport Roads & Maritime Services

PREPARED BY
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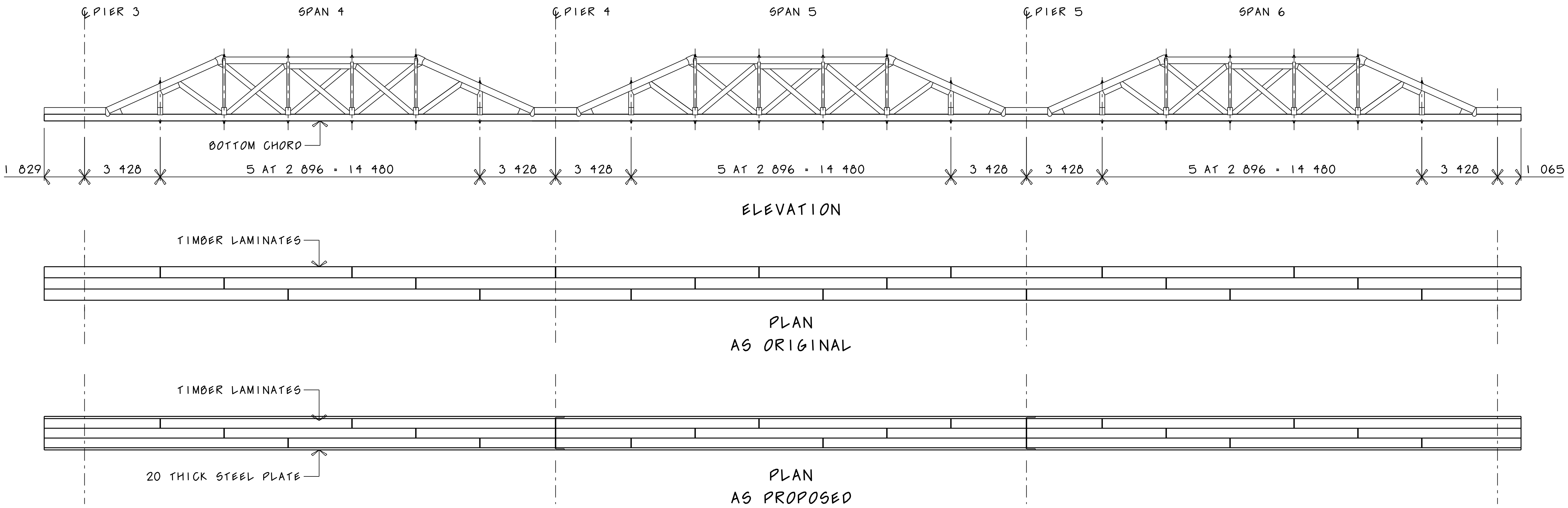
59 DARBY STREET NEWCASTLE
PHONE (02) 4924-0357 FACSIMILE (02) 4924-0301

	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

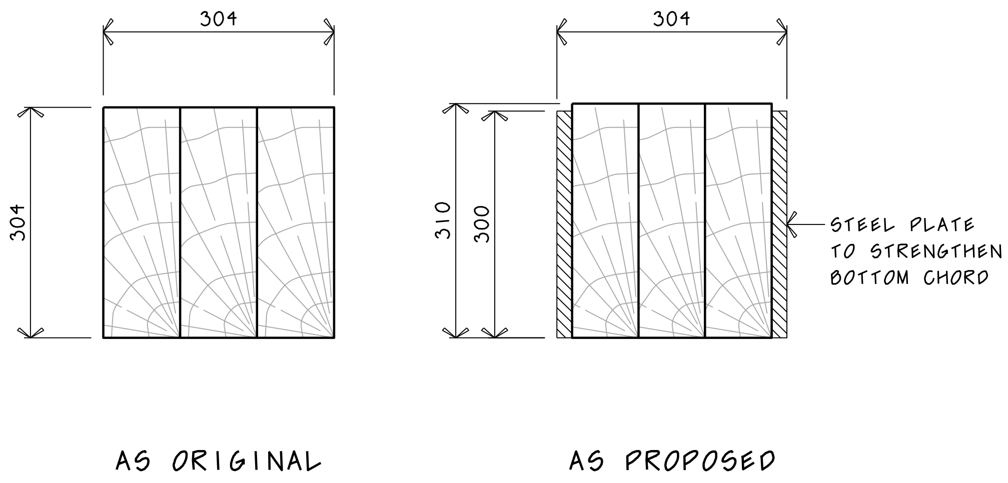
SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 4 OF 9 — ISSUE A

CAD No KA897HTSB_SP.dgn



BOTTOM CHORD TIMBER LAMINATE LAYOUT

NOT TO SCALE



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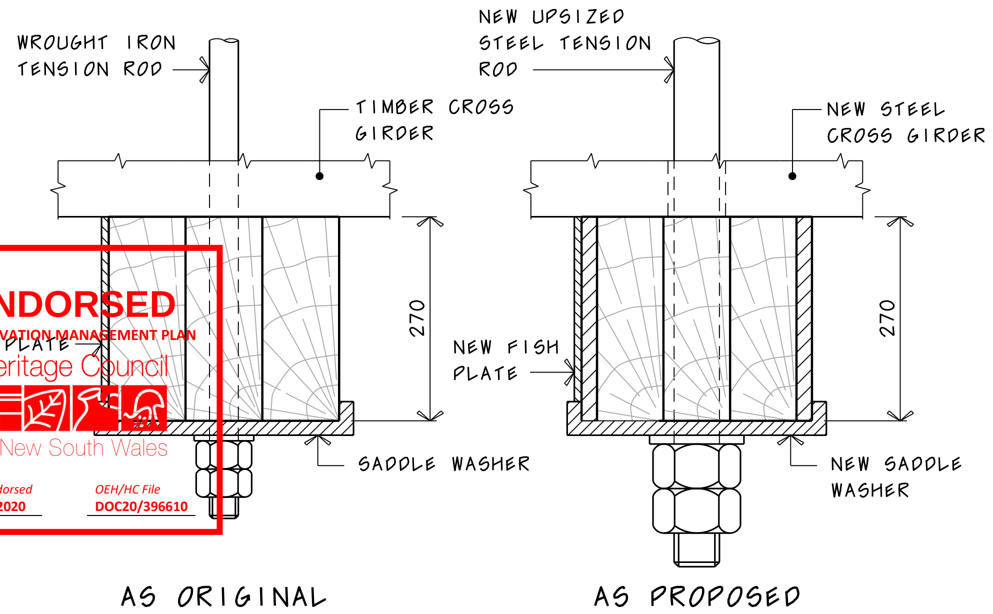

ENDORSED
CONSERVATION MANAGEMENT PLAN
Heritage Council
of New South Wales
Date endorsed 18/12/2020
OEH/HC File DOC20/396610

SECTION AT TENSION ROD

GENERAL NOTES

SCALE AS SHOWN.

ORIGINAL DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE. DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:

- EXISTING TRUSS GEOMETRY IS DISTORTED
- ORIGINAL TIMBER SWAY BRACES HAVE BEEN REPLACED WITH STEEL SWAY BRACES OF DIFFERENT DIMENSIONS
- ORIGINAL FISH PLATES HAVE BEEN REPLACED WITH STEEL PLATES OF DIFFERENT SHAPES AND SIZES
- AN ADDITIONAL ROW OF TIMBERS HAS BEEN ADDED TO BOTTOM CHORD ON SOME SPANS
- ORIGINAL BOTTOM CHORD LAMINATE LAYOUT HAS BEEN LOST ON ALL SPANS

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

ISSUE	DATE	REVISION	PREP	CHECK	AUTH

UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT
TRUSS SPAN - SHEET C

NSW GOVERNMENT — Transport Roads & Maritime Services

PREPARED BY
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	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 5 OF 9 ISSUE A

CAD No KA897HTSC_SP.dgn

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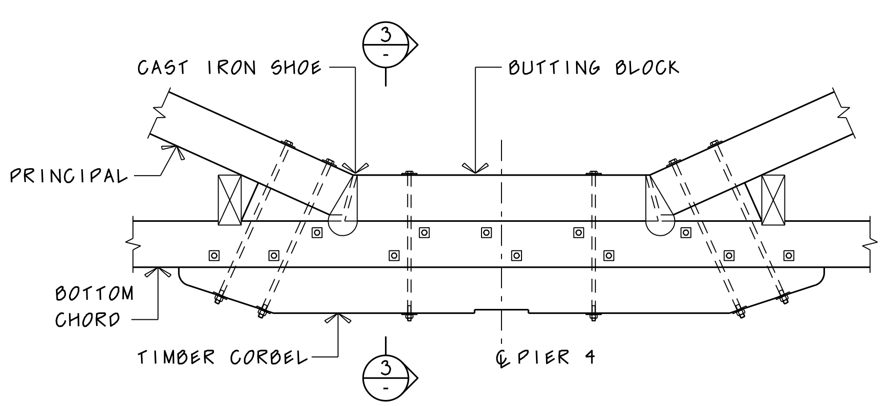
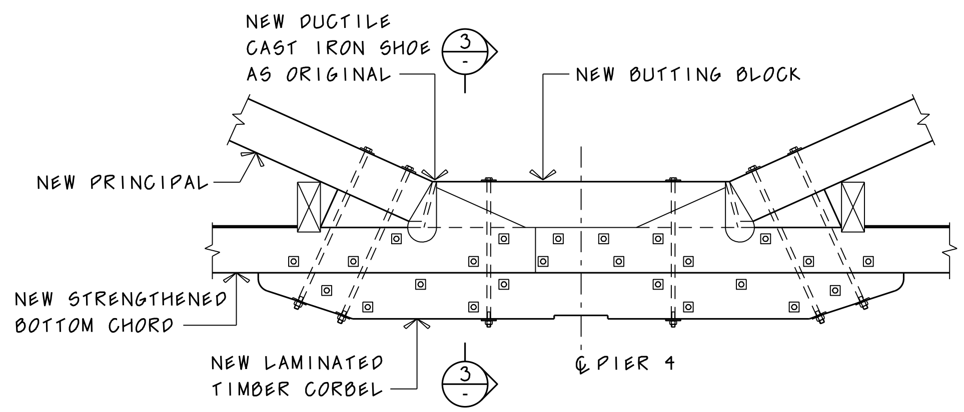


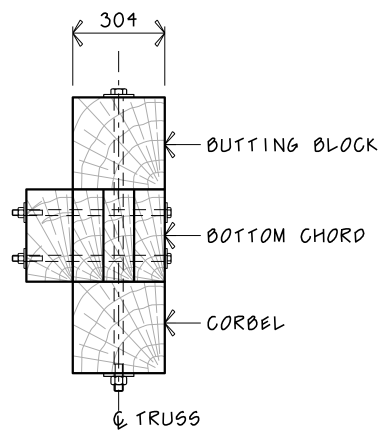
DETAIL A/3

AS ORIGINAL



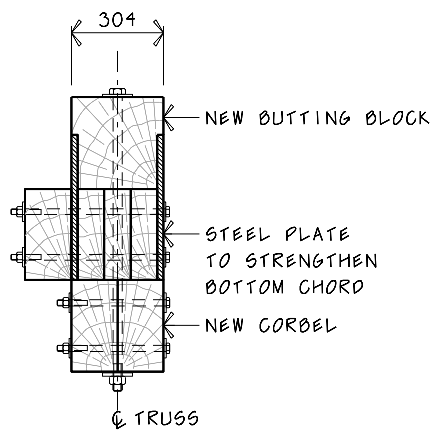
DETAIL A/3

AS PROPOSED



SECTION 3/-

AS ORIGINAL



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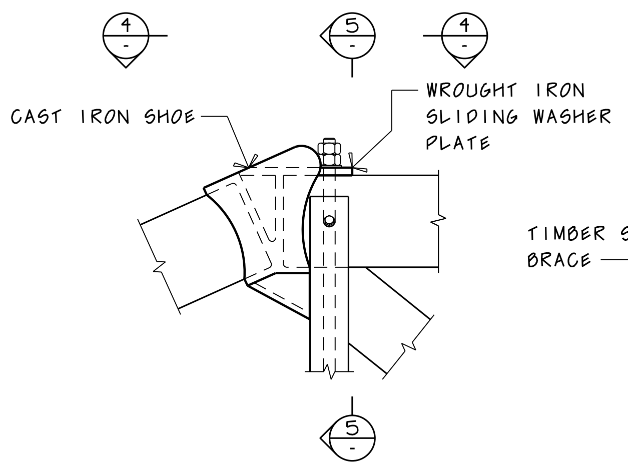
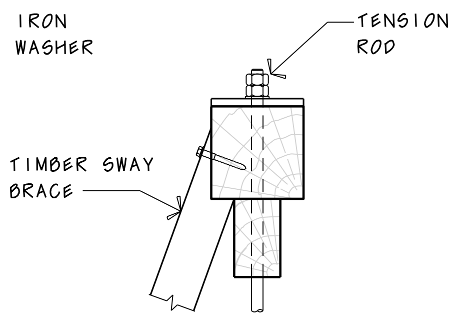
AS PROPOSED



DETAIL B/3



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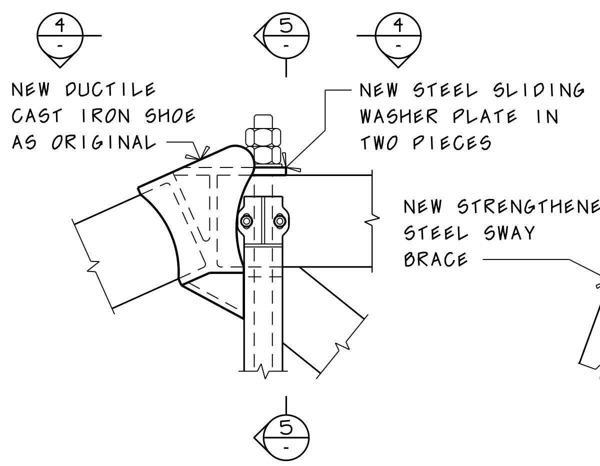
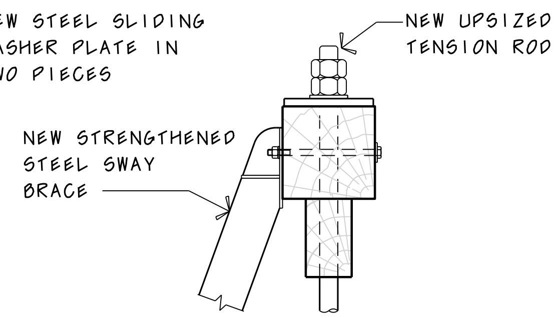


DETAIL B/3



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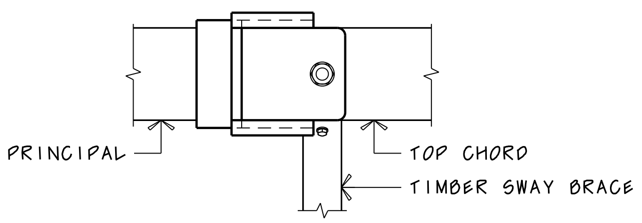
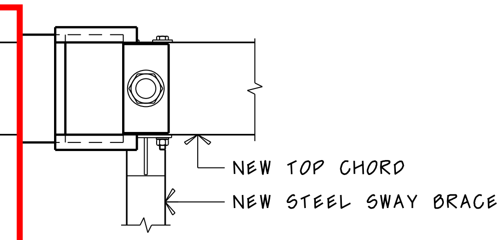


VIEW 4/-

AS ORIGINAL

ENDORSED
CONSERVATION MANAGEMENT PLAN
Heritage Council of New South Wales
Date endorsed 18/12/2020
OEH/HC File DOC20/396610



VIEW 4/-

AS PROPOSED

GENERAL NOTES

SCALE 0 250 500 750mm (250 125) OR AS SHOWN.

ORIGINAL DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE. DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:
- EXISTING TRUSS GEOMETRY IS DISTORTED
- SOME CAST IRON SHOES ARE BROKEN AND SOME HAVE BEEN REPLACED WITH STEEL
- ORIGINAL TIMBER SWAY BRACES HAVE BEEN REPLACED WITH STEEL SWAY BRACES OF DIFFERENT DIMENSIONS
- ORIGINAL TENSION RODS HAVE BEEN REPLACED WITH STEEL TENSION RODS WITH INCREASED DIAMETER

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

ISSUE	DATE	REVISION	PREP	CHECK	AUTH

UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT
TRUSS SPANS - SHEET D

NSW GOVERNMENT — Transport Roads & Maritime Services
PREPARED BY
BRIDGE AND STRUCTURAL ENGINEERING BRANCH
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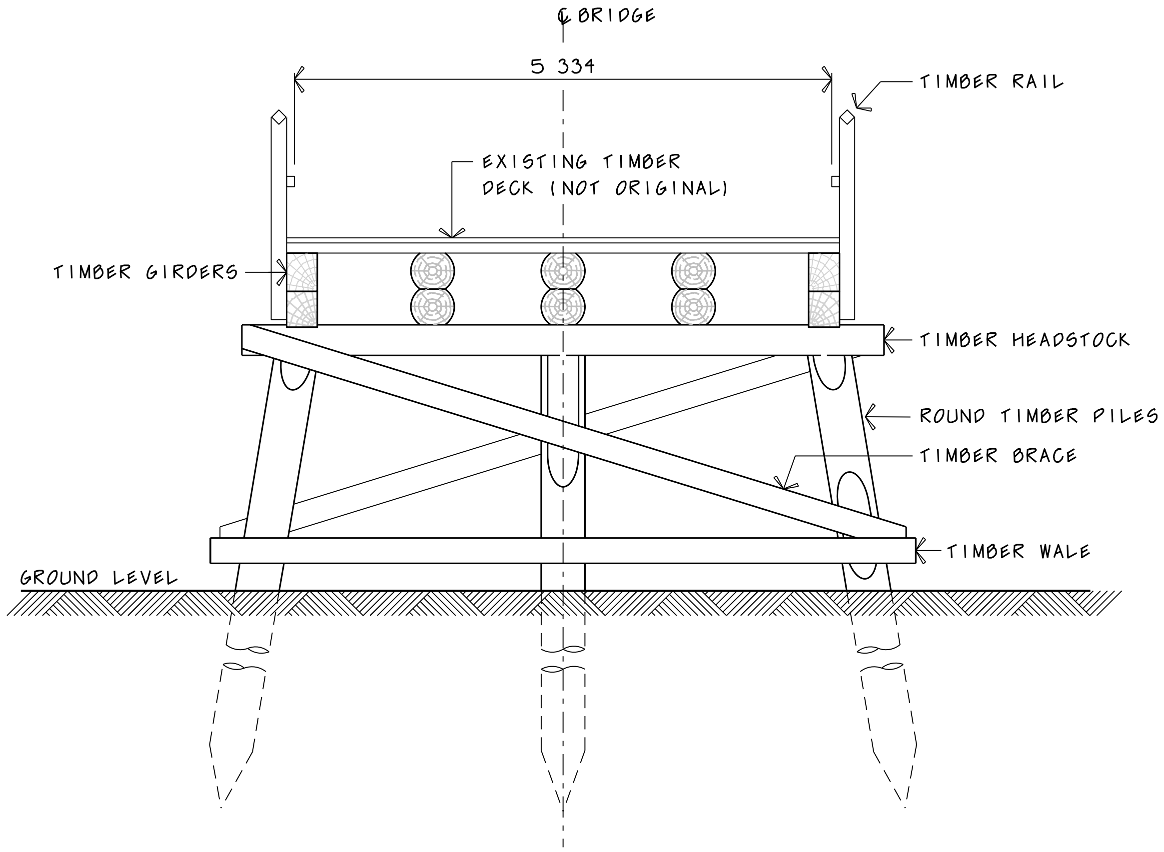
PHONE (02) 8837-0832 FACSIMILE (02) 8837-0023
CLIENT:
HUNTER REGIONAL OFFICE
59 DARBY STREET NEWCASTLE
PHONE (02) 4924-0357 FACSIMILE (02) 4924-0301

	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

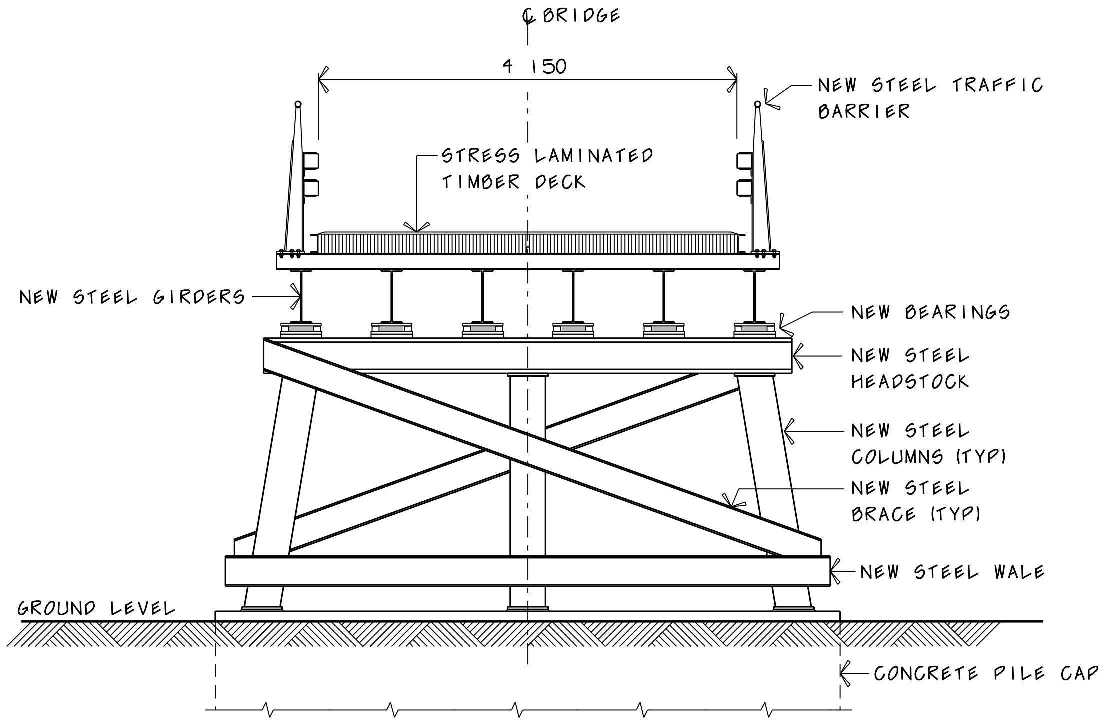
SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 6 OF 9 — ISSUE A

CAD No KA897HTSD_SP.dgn



SECTION 1/1

AS ORIGINAL



SECTION 1/2

AS PROPOSED

PIERS 1 AND 2

PIER 2 SHOWN, PIER 1 SIMILAR

GENERAL NOTES

SCALE 1 000 500 0 1 000 2 000 3 000

ORIGINAL DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE. DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:

- ORIGINAL DECK HAS BEEN REPLACED WITH SPACED TRANSVERSE DECKING OVERLAID WITH LONGITUDINAL SHEETING
- KERBS HAVE BEEN ADDED ON ALL SPANS
- EXISTING PIER GEOMETRY IS DISTORTED
- ALL PILES ARE SPLICED, SOME WITH VISIBLE SPLICES
- ONE TIMBER BRACE HAS BEEN ROTATED ON ONE PIER
- SOME ROUND PILES HAVE BEEN REPLACED WITH SAWN PILES
- ORIGINAL TIMBER WALES HAVE EITHER BEEN BURIED OR REMOVED

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

ENDORSED
CONSERVATION MANAGEMENT PLAN
Heritage Council of New South Wales
Date endorsed 18/12/2020
OEH/HC File DOC20/396610

ISSUE	DATE	REVISION	PREP	CHECK	AUTH
B	22.06.2017	CHANGE PROPOSED PIERS TO STEEL	JP	AN/SC	SD

UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT

PIERS - SHEET A

NSW GOVERNMENT — Transport Roads & Maritime Services

PREPARED BY
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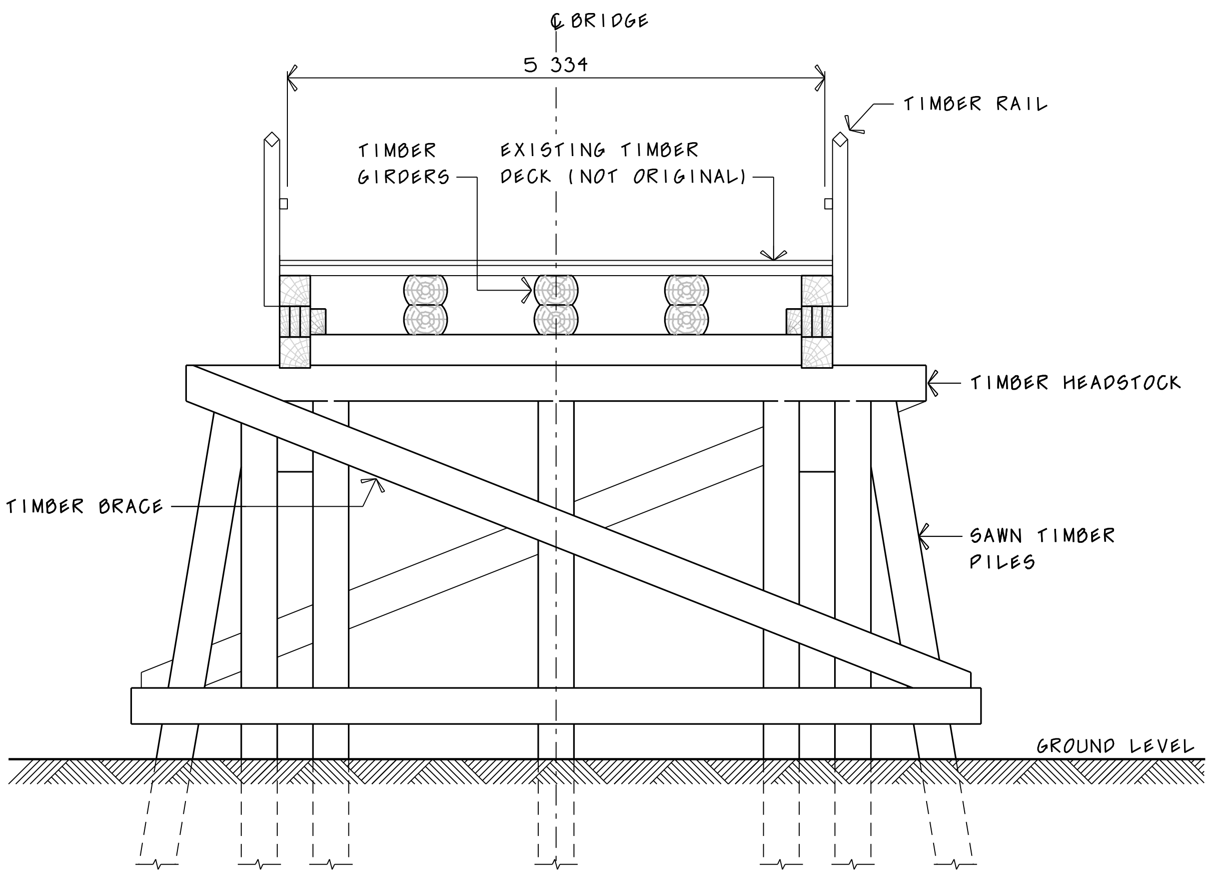
PHONE (02) 8837-0832 FACSIMILE (02) 8837-0023
CLIENT:
HUNTER REGIONAL OFFICE
59 DARBY STREET NEWCASTLE
PHONE (02) 4924-0357 FACSIMILE (02) 4924-0301

	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

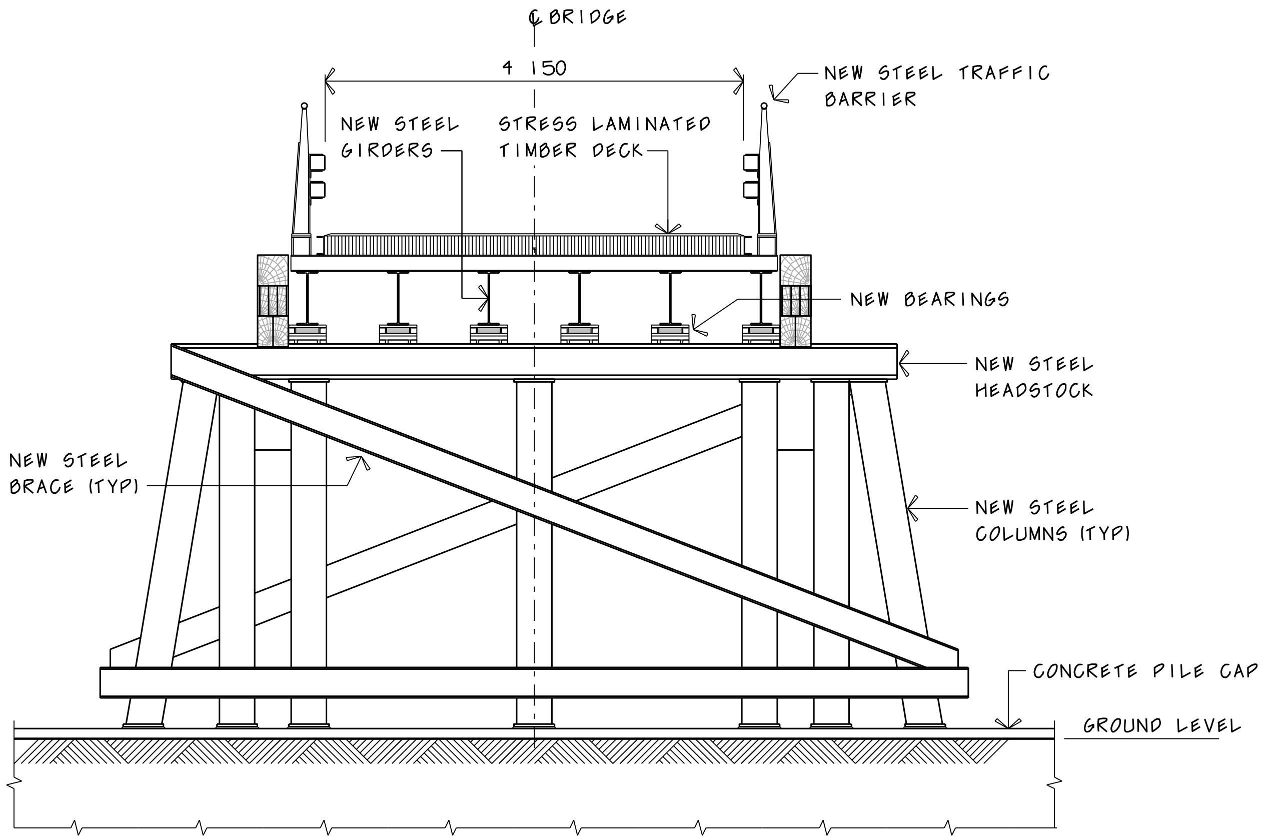
SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 7 OF 9 — ISSUE B

CAD No KA897HPA_B.dgn



SECTION 2/1

AS ORIGINAL



SECTION 2/2

AS PROPOSED

PIER 3

GENERAL NOTES

SCALE 1 000 500 0 1 000 2 000 3 000 OR AS SHOWN.

ORIGINAL DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE. DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:

- ORIGINAL DECK HAS BEEN REPLACED WITH SPACED TRANSVERSE DECKING OVERLAID WITH LONGITUDINAL SHEETING
- KERBS HAVE BEEN ADDED ON ALL SPANS
- EXISTING PIER GEOMETRY IS DISTORTED
- ALL PILES ARE SPLICED, SOME WITH VISIBLE SPLICES

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

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CONSERVATION MANAGEMENT PLAN
Heritage Council of New South Wales
Date endorsed 18/12/2020
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UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT

PIERS - SHEET B

NSW GOVERNMENT — Transport Roads & Maritime Services

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	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

SKETCH No KA897HCS01
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ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 8 OF 9 — ISSUE B

CAD No KA897HPB_B.dgn

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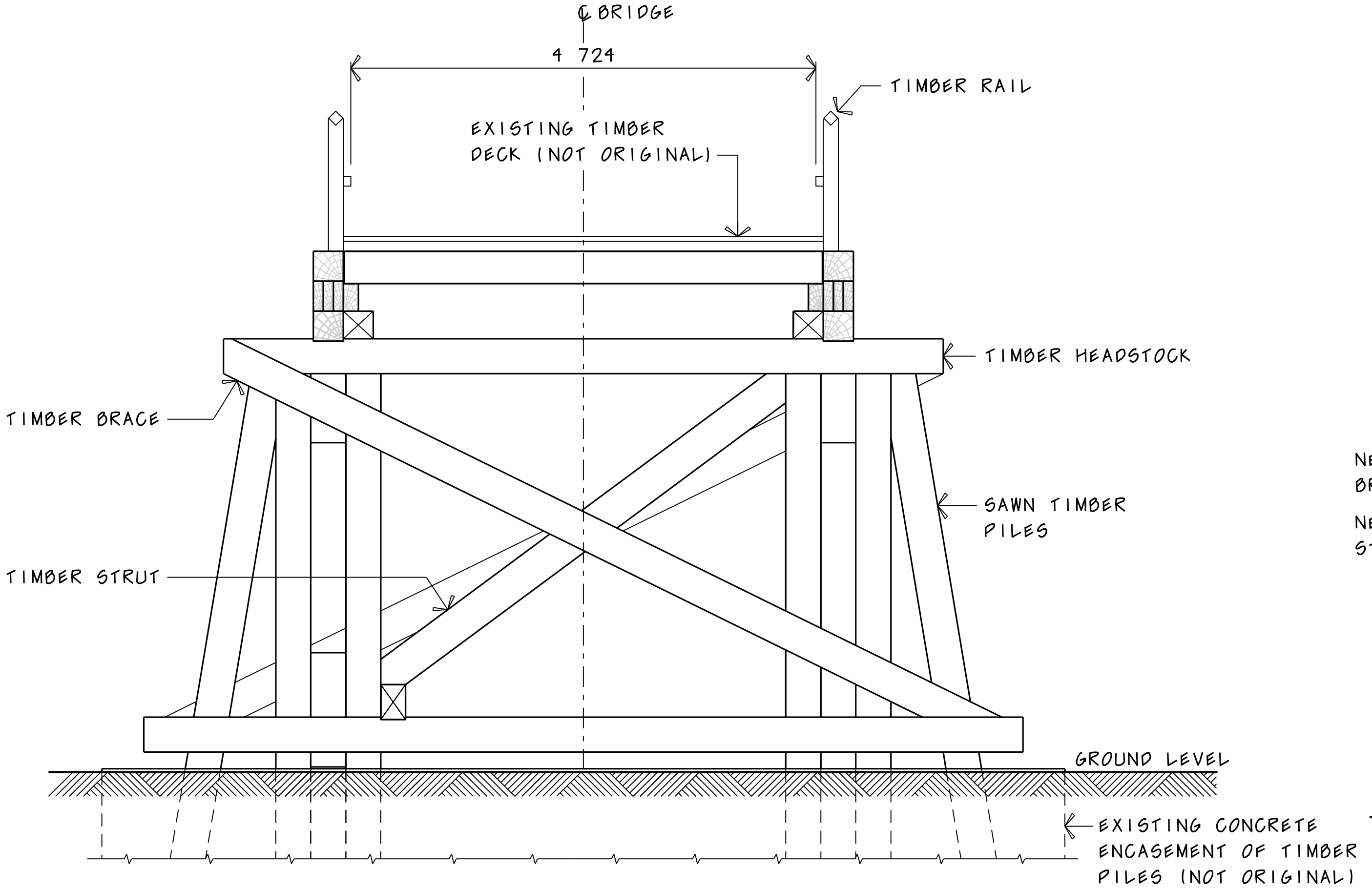
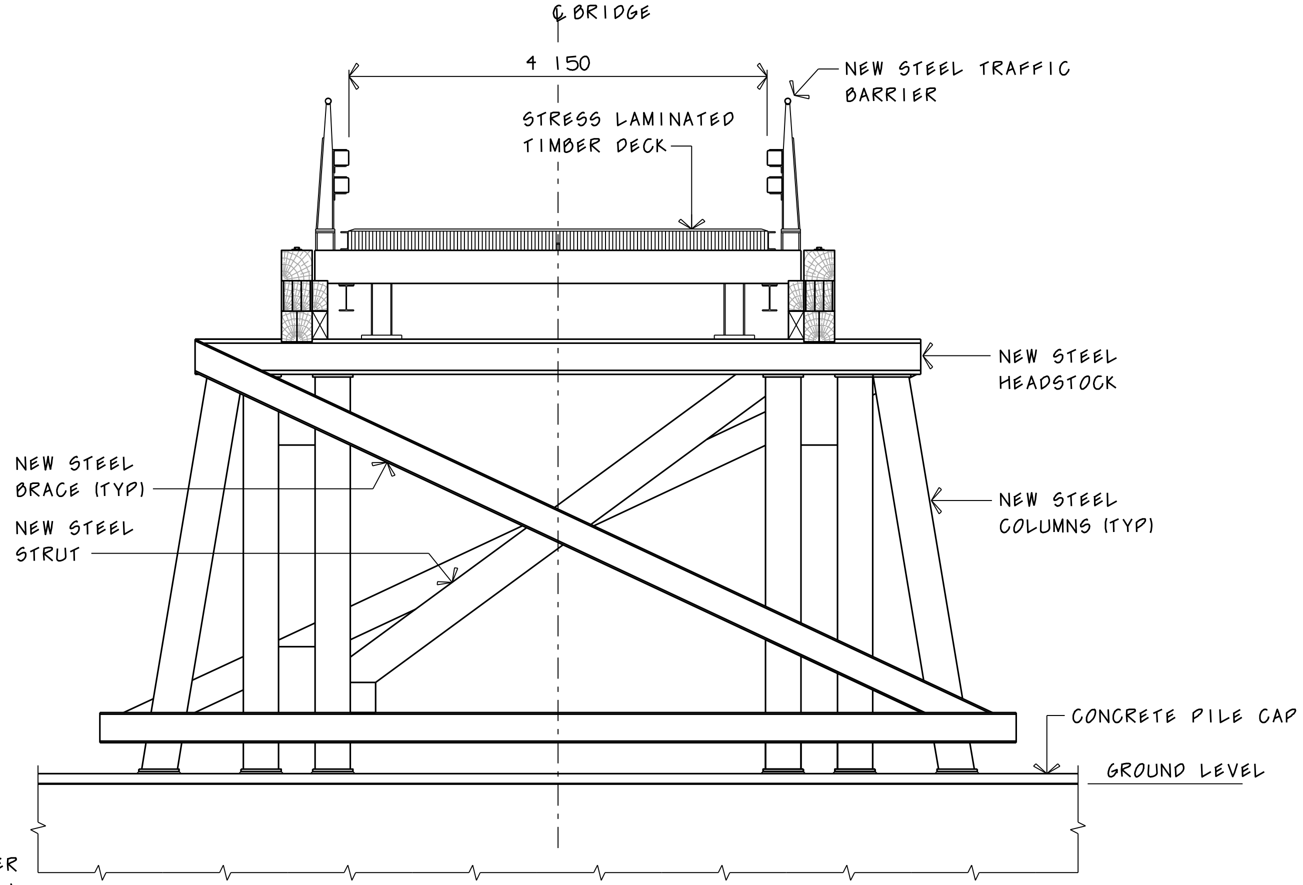


SECTION 3/1

AS ORIGINAL



SECTION 3/2

AS PROPOSED

PIERS 4 AND 5

PIER 5 SHOWN, PIER 4 SIMILAR

GENERAL NOTES

SCALE 1 000 500 0 1 000 2 000 3 000

ORIGINAL DETAILS ARE SHOWN EXCEPT WHERE NOTED OTHERWISE. DIFFERENCES BETWEEN ORIGINAL AND EXISTING INCLUDE:

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- KERBS HAVE BEEN ADDED ON ALL SPANS
- EXISTING PIER GEOMETRY IS DISTORTED
- ONE TIMBER BRACE HAS BEEN ROTATED ON ONE PIER
- ALL PILES ARE SPLICED AND HAVE BEEN ENCASED IN CONCRETE BELOW GROUND LEVEL WITH CONCRETE CLEARLY VISIBLE
- A MIXTURE OF SAWN AND ROUND COLUMNS HAVE BEEN ADDED TO THE PIERS PROPPED OFF THE CONCRETE

FOR OTHER GENERAL NOTES RELATING TO THIS SHEET, SEE SHEET No 1.

ENDORSED
CONSERVATION MANAGEMENT PLAN
Heritage Council of New South Wales
Date endorsed 18/12/2020
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ISSUE	DATE	REVISION	PREP	CHECK	AUTH
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UNCLASSIFIED ROAD — GREAT LAKES LGA

MONKERAI BRIDGE OVER KARUAH RIVER
AT 22km NORTH EAST OF DUNGOG
CAPACITY UPGRADE - HERITAGE CONCEPT

PIERS - SHEET C

NSW GOVERNMENT Transport Roads & Maritime Services

PREPARED BY
BRIDGE AND STRUCTURAL ENGINEERING BRANCH
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CLIENT:
HUNTER REGIONAL OFFICE
59 DARBY STREET NEWCASTLE
PHONE (02) 4924-0357 FACSIMILE (02) 4924-0301

	PREPARED	CHECKED
DESIGN	A NICHOLAS	S CHAINAMYONT
DRAWING	JP	A NICHOLAS

S DESHPANDE 9/12/2016
BRIDGE ENGINEER (REHABILITATION DESIGN)

SKETCH No KA897HCS01
BRIDGE NUMBER B1477
ISSUE STATUS: FOR HERITAGE REVIEW
SHEET No 9 OF 9 ISSUE B

CAD No KA897HPC_B.dgn

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