NOMINATION OF THE

RAILWAY LATTICE BRIDGE AND VIADUCTS

AT

WAGGA WAGGA

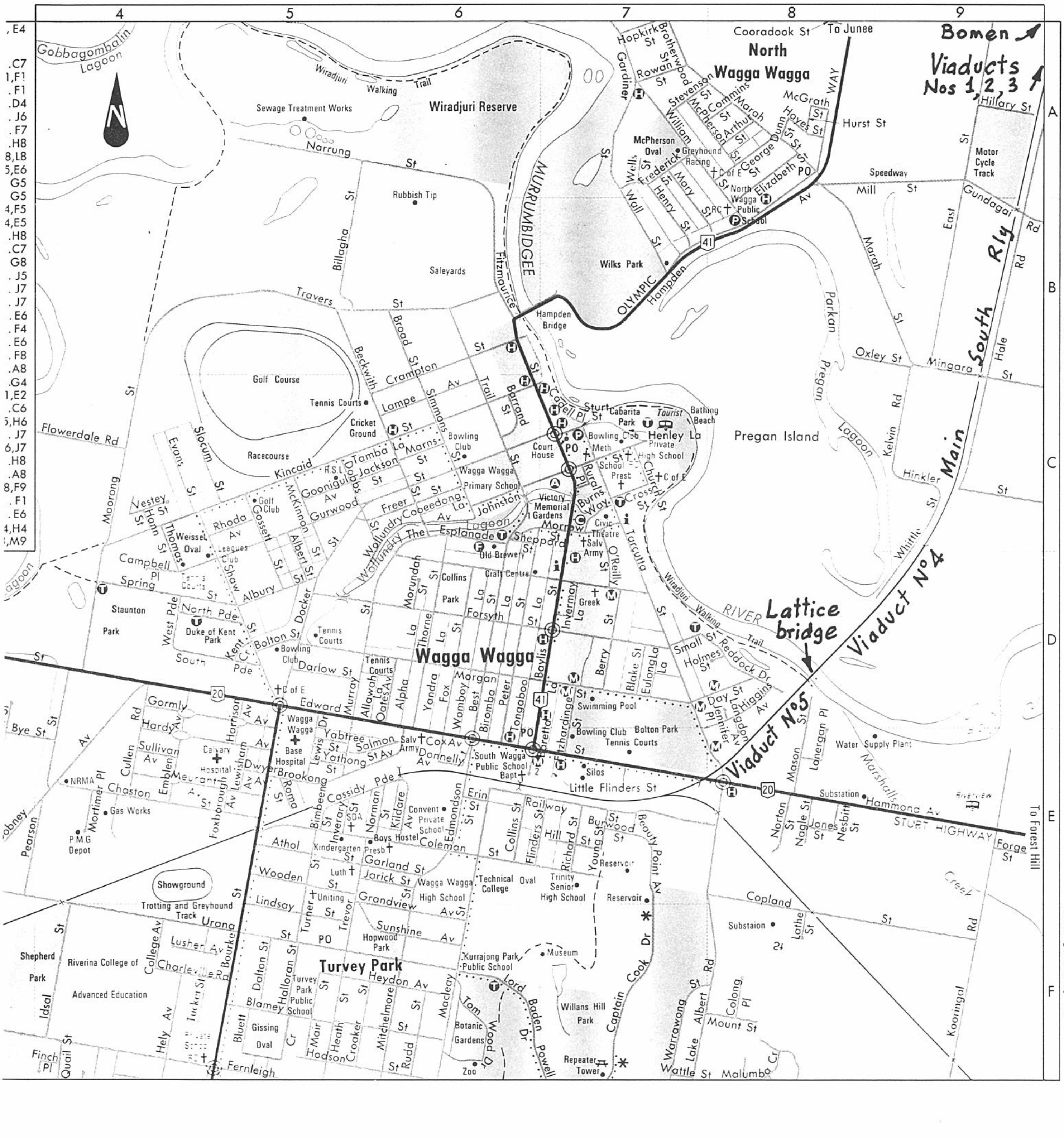
AS

HISTORIC ENGINEERING MARKERS

The lattice wrought iron railway bridge and the original timber viaduct c1890

Engineering Heritage Committee
Sydney Division, I E Aust
May 1995


DARWIN
Katherine
Larrimah
NORTHERN TERRITORY
ALICE SPRINGS
Oodnadatta
SOUTH AUSTRALIA
MARREE
Cook
Tarcoola
Hawker
PORT AUGUSTA
Quorn
Cockburn
Whyalla
PORT PIRIE
Port Lincoln
ADELAIDE
Pinnaroo
Serviceton
Kingston
Mt. Gambier
Port Fairy
QUEENSLAND
CAIRNS
Innisfail
Normanton
Croydon
Forsayth
Ingham
TOWNSVILLE
Ayr
Bowen
MOUNT ISA
Cloncurry
Hughenden
Dajarra
Mackay
Winton
Blair Athol
Longreach
Jericho
ROCKHAMPTON
Springsure
Rannes
Gladstone
Yaraka
Moura
Theodore
Bundaberg
Injune
Quilpie
Charleville
Gympie
Miles
Glenmorgan
Dalby
Cunnamulla
BRISBANE
Dirranbandi
Warwick
Murwillumbah
Moree
Pokataroo
Bourke
Inverell
Grafton
Walgett
Narrabri
Coonamble
ARMIDALE
Cobar
TAMWORTH
BROKEN HILL
NEW SOUTH WALES
Dubbo
Tarce
Roto
Muswellbrook
Parkes
Cessnock
Maitland
ORANGE
NEWCASTLE
Mildura
Cowra
Hay
Griffith
SYDNEY
Balranald
Cootamundra
WOLLONGONG
Swan Hill
WAGGA WAGGA
Junee
GOULBURN
CANBERRA
Echuca
ALBURY
VICTORIA
Ararat
BALLARAT
MELBOURNE
Geelong
Orbost


Bomen
Viaducts Nos 1, 2, 3
Lattice bridge
Viaduct No 4
Viaduct No 5
South Main Rly
North Wagga Wagga
Wagga Wagga
Turvey Park
Wiradjuri Reserve
MURRUMBIDGEE
RIVER
Pregan Island
Gobbagombalin Lagoon
Wiradjuri Walking Trail
Sewage Treatment Works
Rubbish Tip
Saleyards
Golf Course
Tennis Courts
Cricket Ground
Racecourse
Wilks Park
McPherson Oval
Greyhound Racing
North Wagga Public School
Hampden Bridge
Cabarita Park
Tourist
Bathing Beach
Motor Cycle Track
Speedway
Court House
Wagga Wagga Primary School
Victory Memorial Gardens
Civic Theatre
Old Brewery
Craft Centre
Collins Park
Staunton Park
Duke of Kent Park
Weissel Oval
Swimming Pool
Bolton Park
Water Supply Plant
Wagga Wagga Base Hospital
Calvary Hospital
South Wagga Public School
Showground
Trotting and Greyhound Track
Shepherd Park
Riverina College of Advanced Education
Wagga Wagga High School
Technical College
Trinity Senior High School
Reservoir
Museum
Kurrajong Park Public School
Turvey Park Public School
Gissing Oval
Botanic Gardens
Zoo
Willans Hill Park
Repeater Tower
Hopwood Park
Gas Works
P.M.G Depot
NRMA
Silos
Substation
To Junee
To Forest Hill
OLYMPIC WAY
STURT HIGHWAY
Edward St
Fitzmaurice St
Baylis St
Hampden Av
Travers St
Narrung St
Lake Albert Rd
Captain Cook Dr
Lord Baden Powell Dr
Fernleigh Rd
Copland St
Hammond Av
Kooringal Rd
Gundagai Rd
Mill St
Hurst St
Cooradook St

IMPETUS FOR NOMINATION

The purpose of this nomination is to honour the railway lattice bridge and viaducts at Wagga Wagga in their own rights as works of engineering heritage significance.

It is proposed to hold the plaquing ceremony on 11 November 1995, to coincide with a re-enactment by the North Wagga Residents' Association, of the opening of the Hampden Bridge, which has its centenary on the same day. Hampden Bridge was declared an Historic Engineering Marker on 13 February 1993. A copy is attached of the letter from the North Wagga Residents' Association.

NORTH WAGGA RESIDENTS' ASSOCIATION

PRESIDENT:

Fran Geale
Phone (069) 21 5451

SECRETARY:

George Wood-Bradley
6 Hurst Street
NORTH WAGGA WAGGA NSW 2650
Phone (069) 21 5063

August 19, 1994

Mr Paul Hagenbach
Engineering Heritage Committee Sydney Division
Rocky Falls
THE ROCK NSW 2655

Dear Paul

The North Wagga Residents Committee, along with the Wagga Wagga City Council are planning to hold a re-enactment of the opening of the Hampden Bridge to celebrate its Centenary on the 11 November 1995.

We are inviting other groups within the community, such as yours, to participate in the planned festivities. Paul, could you please inform other interested parties by placing this letter on your direct mail.

We are planning to follow as closely as possible the original itinerary with a parade of Dignitaries carried by horse-drawn carriages from either the Wagga Railway Station or the Council Chambers (which ever the Local Traffic Committee approves) accompanied by a band to proceed to the Hampden Bridge where the re-enactment will take place.

Following the re-enactment we are planning a family fun day with a band recital and local singers to entertain the crowd. This family fun day will be held on the North Wagga Common, where we hope groups such as yours will set up a static display in common with the theme and period of the time.

We have also invited such groups as the Wagga Drivers Club, The Clydesdale Stud, Clouty's Amusements etc to participate by providing rides and a hay ride etc for the children.

Other service groups will be invited to participate by providing Bar-B-Que, food, drinks etc the proceeds of which will be used for their respective charities

We sincerely hope that your group can join with us and the other interested groups for a day of fun for everyone concerned.

Yours sincerely

George Wood-Bradley
Secretary North Wagga Wagga Residents Association
gwb.co219895

HISTORICAL SUMMARY

A full account of railway lattice bridges in New South Wales, including the one at Wagga Wagga, and of the viaducts is contained in the two reference papers at the end of this report. However, a summary dealing specifically with the work at Wagga Wagga was considered more useful to readers seeking to have only an overview relevant to this nomination.

The Great Southern Railway was opened to Bomen on 3 September 1878, which is 6 km north of Wagga Wagga and indeed was known as North Wagga Wagga at the time. The line was taken across the flood plain on a series of timber viaducts and a temporary timber bridge over the river to allow trains to reach South Wagga, now Wagga Wagga, a year later.

The original viaducts comprised timber girder spans, on timber trestles at 29 feet 6 inches (9 metres) centres, consisting of four parallel girders topped by cross-planks to carry the single-line ballasted track. A total of 316 spans were built, hastily, consequently the timber used had not been sufficiently seasoned. This was a significant factor contributing to the poor performance of these viaducts leading to their replacement during 1897-1901.

Construction of the permanent iron bridge over the river commenced in May 1879 and was completed in November 1880 and was brought into regular use on 23 January 1881.

At the time, the lattice girder was the main type of structure for bridges over 100 feet span, road and rail, and had become the favoured choice of John Whitton, Engineer-in-Chief for Railways in New South Wales. He had 12 built of which 11 are extant but only 8 are in service. Three are in the South-West of New South Wales. Those at Wagga Wagga (1881) and Albury (1884) both on the Great Southern Railway are still in service, whereas the one south of Narrandera (1884) on the branch line to Jerilderie is not in use.

The Wagga bridge was the third railway lattice bridge and was the longest at the time of construction. It consists of 4 wrought iron (not steel) lattice girders on 9ft diameter cylindical piers at 159 feet centres thereby providing a clear waterway of 150 feet per span. The four spans are continuous over the piers rather than being four separate simply-supported spans.

A temporary timber staging was erected across the main channel of the Murrumbidgee River with rails on top to support a travelling crane which was used by J. S. Bennett, on behalf of contractor A. and R. Amos, for constructing the piers and then the superstructure of the bridge.

The 9ft diameter cast iron cylinders were supplied in short segments from Middlesborough, England, and were stacked one on top of each other so as to become heavy enough to sink into the river bed. Open dredging took place down to bed rock and then the cylinders were filled with concrete. The maximum depth below rail level was 156 feet.

The superstructure was designed by Whitton's staff and checked by consulting engineer John Fowler in London, England. It was then manufactured in Glasgow by P. W. McClellan and the 750 tons of structural pieces was shipped to Sydney and transported to the site where it was assembled like a giant Meccano set.

The completed bridge was load tested on 16 December 1880 using three steam locomotives weighing a total of 185 tons, the maximum deflection was only 0.75 of an inch. This high measure of stiffness has contributed greatly to the durability of the bridge.

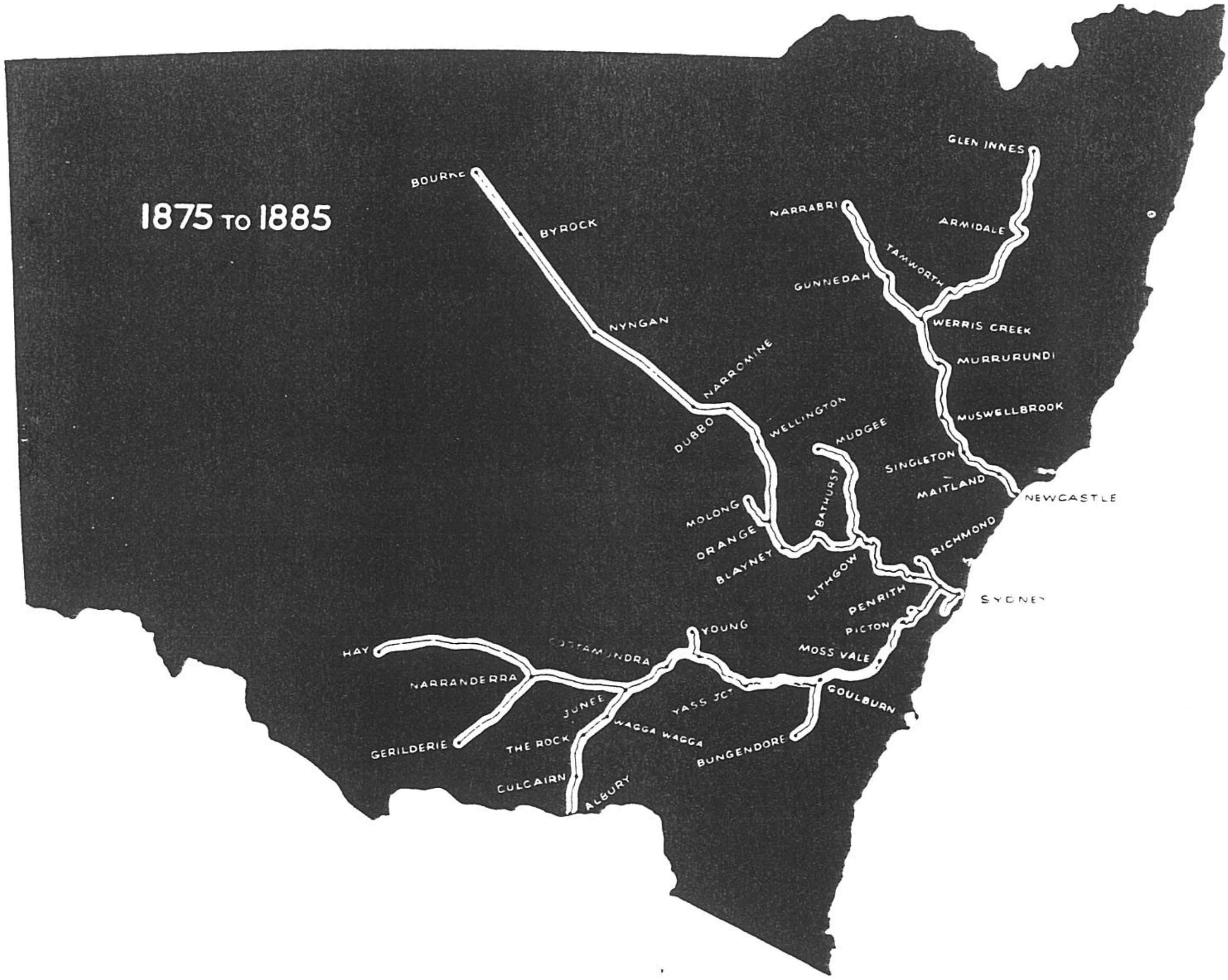
The lattice bridge has been in service ever since.

The original design had cross-arches (see photograph on the front page), over the railway vehicle height, joining the top flanges of the main lattice girders, but they were not adequate bracing to guard against a lateral buckling failure of the compression top flanges. In 1929 a series of strong rectangular portal frames were substituted which enabled the bridge to carry the heaviest steam locomtive, the D57, and the latest diesel 90 class locomotives, without speed restrictions.

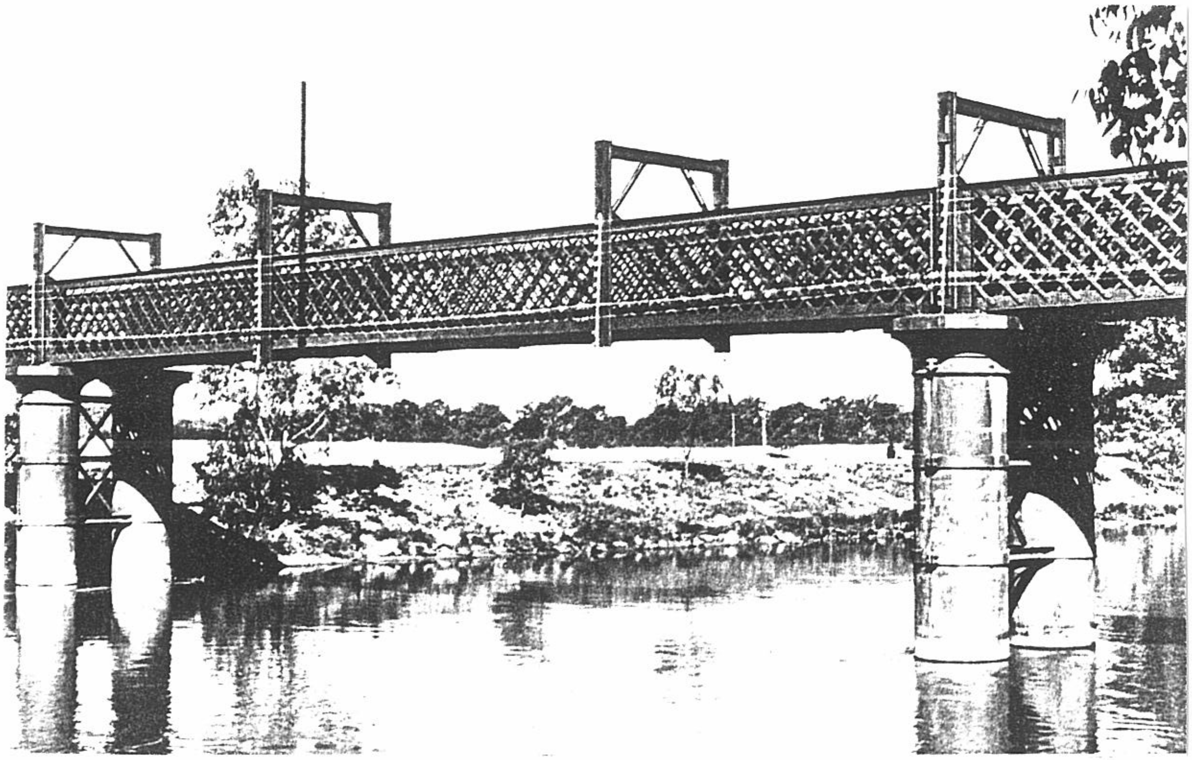
As for the viaducts, the original timber construction deteriorated rapidly and was constantly being repaired which caused severe interruptions to rail traffic. By 1895 the decision was made to replace all six viaducts, 4 long and 2 short, with steel plate web girders supported by steel trestles fabricated by Mountney and Co. of Pyrmont, Sydney, using steel imported from England.

Construction was carried out by railway day labour during 1897-1901 and the new viaducts have been in continuous service ever since. In 1976 the short sixth viaduct was replaced by a new set of girders associated with the widening of Edward Street, the Sturt Highway, so there are now 5 of the 1901 viaducts in use.

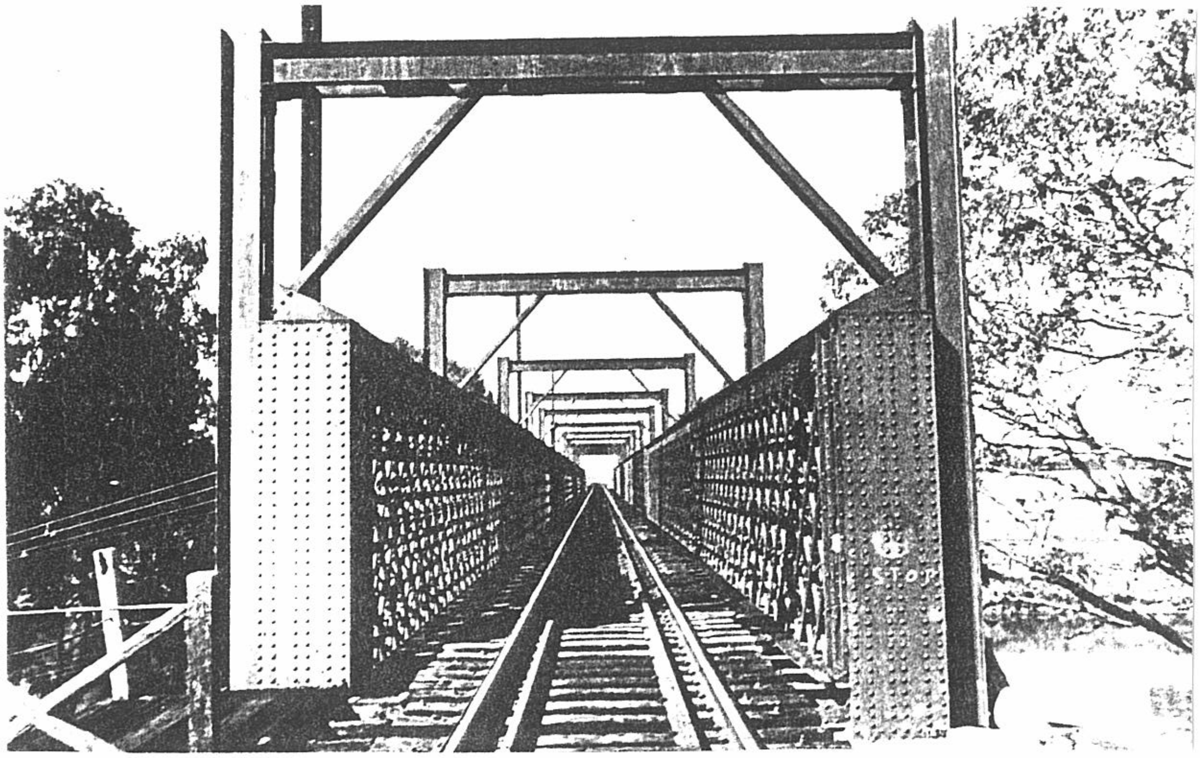
The combination of latice bridge and viaducts it is still one of the longest river crossings in New South Wales.



The New South Wales railway system at the time of building the lattice bridge and viaducts at Wagga Wagga.



A river span of the lattice bridge which shows the 1929 sway frames.



An axis view of the lattice bridge with the overhead rectangular sway frames.

STATEMENT OF SIGNIFICANCE

THE LATTICE BRIDGE

The railway lattice bridge over the Murrumbidgee River at Wagga Wagga will be virtually 105 years old on the proposed day of plaquing.

The bridge has been in continuous service since its completion in November 1880 and has, for more than half its life, carried rail traffic that is much heavier than its original design load.

Although important structural modifications have been made, the bridge is largely original in appearance and style of construction.

It was the third of the twelve lattice bridges designed and constructed between 1872 and 1887 under the supervision of John Whitton, Engineer-in-Chief for Railways in New South Wales. Currently it is the 2nd oldest in service and the greatest in length.

The family of lattice bridges, and the girder bridges at Menangle and Penrith, are the supreme examples of the domination of British bridge technology in New South Wales prior to the change over to American style bridges in the 1890s.

Together with the lattice bridge over the Murray River at Albury, the Wagga bridge allowed the first linking by rail of two colonial capital cities, Sydney and Melbourne, on 14 June 1883.

THE VIADUCTS

There are currently five railway viaducts across the Murrumbidgee flood plain between Bomen and Wagga Wagga, 4 long and 1 short. The total number of spans is 310 with an aggregate length of 1.75 miles (2.8 km), the longest set of viaducts in service.

The present viaducts are steel deck plate web girders which replaced the original timber girder viaducts built in Whitton's time. The replacement work was carefully planned and took nearly 4 years to completion in 1901, without delay to traffic.

It was the largest timber bridge replacement project until after World War II and was also the largest application of the relatively new material, steel, until construction of the North Coast Railway bridges 1913-1923.

The successful completion of this major work was a clear demonstration of the ability of local fabricators, and railway engineers and staff to deal with a project of this magnitude which would previously have been done entirely by contract using imported bridge units.

The viaducts have been in continuous service for 94 years without speed restrictions being imposed for the faster, heavier rail traffic.

COLLECTIVELY

The railway lattice bridge and viaducts at Wagga Wagga have been one of the most cost effective engineering works from the colonial period.

By maintaining the rail link through the Riverina District and on to Melbourne for over 100 years, they have facilitated enormous benefits (social and commercial) to the Riverina, Victoria and New South Wales, and more recently to Australia through the standard gauge line to Melbourne.

HERITAGE STATUS

The lattice bridge is on the Register of the National Estate and it and the viaducts are Classified by the National Trust (NSW).

Commemorative Plaque Nomination Form

Date......May 1995......

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
Engineering House
11 National Circuit
BARTON ACT 2600

From....Engineering........
....Heritage Committee,....
Sydney Division, IE AUST
Nominating Body

The following work is nominated for a:-

- * ~~National Engineering Landmark~~
- * Historic Engineering Marker

*(delete as appropriate)

Name of work..Railway lattice bridge and viaducts Wagga Wagga........

Location, including address and map grid reference if a fixed work.............
....Flood plain of Murrumbidgee River north of Wagga Wagga........

....

Owner......State Rail Authority of NSW........

....

The owner has been advised of the nomination of the work and has indictated (attach a copy of letter if available)....Owner approves, see letter attached

....

Access to site......Accessible, except at track level........

Future care and maintenance of the work....Continuing maintenance,............
both items assured of continuing long service life

Name of sponsor......N/A........

For a NEL, is an information plaque required?......N/A........

....
Chairperson of Nominating Committee

....
Chairperson of Division Heritage Committee/Panel

ADDITIONAL SUPPORTING INFORMATION

Name of work...Railway lattice bridge and viaducts at Wagga Wagga

Year of construction or manufacture......1880 (bridge) 1901 (viaducts)

Period of operation......105 years and 94 years

Physical condition......Excellent for both

Engineering Heritage Significance:-

Technological/scientific value....Good example of railway lattice bridge

Historical value.2nd oldest railway lattice bridge in service and longest

Social value....Assured railway services to and beyond Wagga Wagga

Landscape or townscape value.......Not assessed

Rarity......N/A

Representativeness..One of 12 lattice railway bridges in NSW

Contribution to the nation or region...Maintained safe continuous rail services

Contribution of engineering...A good example of British bridge technology

Persons associated with the work....John Whitton, John Fowler

Integrity..Original construction, except for 1929 overhead frames

Authenticity..A surviving example of colonial railway lattice bridges

Comparable works(a) in Australia...Murray River bridge, South Australia

(b) overseas......Not researched

Statement of significance, its location in the supporting documentation......

Preceeds this nomination form

Citation (70 words is optimum)........

The proposed words follow this nomination form

Attachments to submission (if any)......Nil

Proposed location of plaque (if not at site)..At southern end of bridge

FREIGHT RAIL
SOUTH

Station Place,
Wagga Wagga NSW 2650

Tel: (069) 22 0444
Fax: (069) 22 0477

Dick Smith
Regional General Manager, South

PO Box S-150,
South Wagga Wagga NSW 2650

Prof Henry J Cowan
Secretary
Sydney Division
Engineering Heritage Committee
The Institute of Engineers, Australia
PO Box 138
Milsons Point NSW 2061

23 February, 1995

Dear Professor Cowan,

Thank you for your letter on behalf of the Engineering Heritage Committee about the plaquing of the railway lattice bridge in Wagga Wagga which I received 10 February.

I am happy to approve and support your committee's project to plaque the railway bridge over the bridge here at Wagga Wagga

May I suggest that you contact my Regional Engineer Civil, Richard Franzi, providing fuller information particularly about the preservation of the work to which you referred in your letter. Richard can be contacted in my office here in Wagga Wagga or by telephoning 069 220 495.

Please do not hesitate to contact me if I may be of further assistance.

Yours faithfully

R. J Smith
Regional General Manager South

PROPOSED WORDS FOR THE PLAQUE

HISTORIC ENGINEERING MARKER

I E Aust Crest

RAILWAY LATTICE BRIDGE AND VIADUCTS AT WAGGA WAGGA

THIS RAILWAY CROSSING OF THE MURRUMBIDGEE RIVER AND FLOOD PLAIN WAS PLANNED BY JOHN WHITTON, ENGINEER-IN-CHIEF FOR RAILWAYS 1856-90. ASSEMBLED FROM COMPONENTS MANUFACTURED IN ENGLAND, THE 4-SPAN CONTINUOUS WROUGHT IRON LATTICE BRIDGE WAS COMPLETED IN NOVEMBER 1880. THE ORIGINAL TIMBER VIADUCTS WERE COMPLETED IN 1879 THEN REPLACED BY THE PRESENT STEEL VIADUCTS DURING 1897-1901. AS PART OF THE RAIL LINK BETWEEN SYDNEY AND MELBOURNE THROUGH THE RIVERINA, THESE STRUCTURES HAVE BEEN OF IMMENSE NATIONAL VALUE. (78 WORDS)

DEDICATED BY
THE INSTITUTION OF ENGINEERS, AUSTRALIA
AND THE STATE RAIL AUTHORITY OF NSW. 1995

JOHN WHITTON

Engineer-in-Chief for Railways, New South Wales, 1856-1890.

South Wales, advertised in April 1852 t
he had various types of American revolv
for sale 'without which neither their li
or gold can be called safe' on the diggin
In 1854 he denied a rumour that he w
going to retire from business. About 18
he moved to 69 King Street, which beca
known as Cannon House.

In 1841 Whitfield had joined other spo
men to form the Sydney Union Club of A
tralia for pigeon-shooting. An accomplish
shot, he won a handsome pigeon gun a
match in 1842 and a silver cup valued
twenty guineas at the 1843 Anniversa
Day shoot. In the 1860s he held shoot
matches at his home, Ormeau View, n
part of St Ignatius's College, Riverview.
1862 he became armourer to the New Sou
Wales Volunteers but his appointment w
cancelled next year.

On 4 November 1864 Whitfield, aged
was shot dead at the door of his shop b
dismissed employee Patrick McGlinn. W
George Hill [q.v.] as a witness, he
buried in the Anglican section of Cam
down cemetery. On 30 May 1853 at St P
ip's Church, Sydney, he had marrie
widow Marianne Yeates, née Warman;
predeceased him on 11 April 1864. He
survived by two daughters of his first w
Margaret (d. 1851), and his business
carried on until 1866 by his nephew Willi
John Whitfield, who was granted admi
tration of his personalty, valued at £300

McGlinn was tried before Sir Alf
Stephen [q.v.] on 20 December; des
medical suggestions that he was insane,
jury found him guilty and he recei
sentence of death, but it was commuted
life imprisonment.

R. B. Shannon, *Colonial Australian g
smiths* (Syd, 1967); *Syd Monitor*, 21 May,
Oct 1834, 9 Oct, 27 Dec 1839; *Australian*
July 1841, 14 May 1842; *A'sian Chronicle*
Mar 1842, 28 Jan 1843; *Bell's Life in Sydn*
19 June 1847, 3 Apr 1852, 10 June 1854, 9
1858, 1 Sept 1860; *SMH*, 16 Feb 1861, 10
8 Apr 1865; *Empire* (Syd), 5, 7, 8 Nov, 21
1864; *ISN*, 16 Nov 1864; Surveyor-general, M
cellaneous papers 7/2720 *and* Col Sec lett
1863, no 5120, 7138, 1864, no 128 (NSWA).

R. B. SHANNO

WHITTON, JOHN (1820-1898), engineer, was born near Wakefield, Yorkshire, England, son of James Whitton, land agent, and his wife Elizabeth, née Billington. Articled for seven years to John Billington, of Wakefield, he gained engineering and architectural experience preparing plans and tenders for railway construction and waterworks. In 1847 he was engineer for the Manchester, Sheffield and Lincoln railway, and in 1852-56 supervised the building of the Oxford, Worcester and Wolverhampton line. In 1854 he was elected a member of the Institution of Civil Engineers, London, and on 27 March 1856 was appointed engineer-in-chief at a salary of £1500 to lay out and superintend the construction of railways in New South Wales. With his wife Elizabeth, née Fowler, whom he had married about 1856 at Ecclesfield Church, Yorkshire, he arrived in Melbourne in the *Royal Charter* in December and reached Sydney on the fourteenth.

Whitton found in New South Wales 23 miles of 4 ft. 8½ ins. gauge railway, 4 locomotives, 12 passenger carriages and 40 trucks. In January 1857 before the Legislative Assembly select committee on the sole commissioner of railways incorporation bill, he vainly advocated conversion to the 5 ft. 3 ins. gauge adopted in Victoria and South Australia, and the extension of the railway from Redfern to Hyde Park in the city. He reorganized accounting and costing and took charge of the rolling stock, line maintenance and workshop departments. He resisted Governor Denison's proposal to construct 4000 miles of light, narrow-gauge tramways to be worked by horses and in the 1860s was constantly hampered by the government's uncritical acceptance of the lowest tenders for railway construction.

In April 1865 allegations of fraud were made against Whitton and his brother-in-law Sir John Fowler, an engineer and inspector of railway materials bought in England by the New South Wales government; the charges were proved groundless by W. C. Mayne [q.v.], agent-general for New South Wales. The 1870 select committee on railway extension chaired by (Sir) William Macleay [q.v.] recommended the construction of cheap narrow-gauge railways, necessitating a break of gauge within the colony, as well as at the border; estimates were prepared but Whitton, determined to sabotage the committee's recommendation, suspended all surveys and new work.

With the aid of E. C. Cracknell [q.v.] he overcame the engineering problems, partly caused by the government's cheese-paring, in building the Blue Mountains line; it included two great zigzags and was opened on 4 April 1876. In 1880-85 the unprecedented growth in railways, one thousand miles of new track and nine million more passengers, exposed existing inadequacies in administration and exacerbated the friction between Whitton and Commissioner C. A. Goodchap [q.v.]. The 1884 royal commission into railway bridges exonerated Whitton of the charges of faulty design and of using inferior materials. In 1888 Sir Henry Parkes's [q.v.] Government Railways Act reorganized the department and Goodchap's subsequent resignation made Whitton's position easier.

In 1886 and 1887 he had submitted drawings for a proposed suspension bridge across Sydney Harbour from Dawes Battery to Milson's Point. On 1 May 1889 the Hawkesbury River bridge was opened; it was the final link in the railway system from Brisbane through Sydney to Melbourne and Adelaide and Whitton had fought for adequate finance for it. He was a member of the Hunter River floods commission 1869-70, the Sydney, City and Suburban Sewage and Health Board 1875-77, and the Board for Opening Tenders for Public Works 1875-87; he was a New South Wales commissioner for the Melbourne International Exhibition in 1880.

Granted a years leave on 29 May 1889, Whitton retired on 31 May 1890 with a pension of £675, and visited England in 1892. He had supervised the laying of 2171 miles of track on which no accident had occurred attributable to defective design or construction. Parkes regarded him as 'a man of such rigid and unswerving integrity, a man of such vast grasp, that however his faults may occasionally project themselves into prominence, it would be difficult to replace him by a man of equal qualifications'. Survived by his wife, one son and two daughters, he died of cardiac disease on 20 February 1898 at Mittagong, and was buried in the cemetery of St Thomas's Church of England, North Sydney. His estate was valued for probate at £10,396.

J. Rae, *Thirty-five years on the New South Wales railways* (Syd, 1898); Dept of Railways, *The railways of New South Wales 1855-1955* (Syd, 1955); *V&P* (LA NSW), 1859-60, 3, 239, 1892-93, 3, 77; *PD* (NSW), 1887, 1890; *NSW Railway and Tramway Mag*, 1 Dec 1920; R. L. Wettenhall, 'Early railway management legislation in New South Wales', *Tas Univ Law Review*, July 1960; *T&CJ*, 14 Sept 1878; *Bulletin*, 1 Sept 1883; *Sydney Mail*, 26 Feb 1898; *Australasian*, 5 Apr 1890; *Old Times*, July 1903; I. M. Laszlo, Railway policies and development in northern New South Wales 1846-1889 (M.A. thesis, Univ New England, 1956); Parkes letters (ML).

C. C. SINGLETON*

WHITTY, ELLEN (1819-1892), best known as Mother Vincent, Mercy Sister, was born on 3 March 1819 near Oilgate in County Wexford, Ireland, daughter of William Whitty and his wife Johanna, née Murphy. At 19 Ellen joined the Sisters of Mercy, a Roman Catholic Order founded in 1831 for education and social work. Influenced by the foundress Catherine McAuley who prepared her for religious profession, she was intelligent, quick and sure
judgment and within a decade was
cted to the highest post in the Order as
verend Mother of the Dublin Head-
use. She coped with the burden of social
rk resulting from the famine of the
40s and organized the preparation of
ters to go with the flood of emigrants.
1854 Fr Robert Whitty, her brother, was
ar-general to Cardinal Wiseman at
estminster, and through him and Fr
ter Cardinal) Manning, the British gov-
ment invited her to send Sisters to nurse
wounded in the Crimea. After the war
established homes for neglected chil-
n and for unmarried mothers.
n 1860 Mother Vincent and five Sisters
re invited by Bishop James Quinn [q.v.]
become the first women religious in the
ly formed diocese of Queensland. She
ked forward to this missionary venture,
the reluctance of her community to
her was overcome by the command of
chbishop Cullen [q.v.]. They arrived in
stralia in the *Donald Mackay* in April
1. Mother Vincent's problems in
eensland stemmed partly from the trend
vards centralized and secular state edu-
ion, but more from the bishop's autoc-
y. She wanted to have her schools in-
endent yet adapted to a pluralist society
so open to all creeds; but Quinn, unlike
er bishops, wished her to graft the con-
t schools on to the state system, pre-
ving the right to choose teachers and
ts. She eventually agreed.
Mother Vincent was unable to tolerate
degree of control which the bishop
ight over purely conventual matters.
e tension resulting when he demoted her
the ranks in 1865 could have wrecked
foundation or forced her to withdraw
for her profound spirituality. In 1870
Quinn's instructions she returned to
land to recruit nuns and he appointed
assistant to the Queensland head of the
der, an office which she retained until
death.
Her schools flourished though some of
projects did not, notably a hospital and
rk with Aboriginals. At her death,
enty-six Mercy schools, mainly along the
stline to Townsville, had 222 Sisters
ith 7000 pupils. At Nudgee there was a
Mercy Training College for teachers. Mother Vincent had commenced a secondary school (All Hallows') many years before the state entered this field. She duplicated in Brisbane the types of social work she had pioneered in Dublin, and provided a link between all forms of service in regular home visitation. She died in Brisbane on 9 March 1892 and was buried in Nudgee cemetery. Her work has stood the test of a century of change.

Conference on The Protection
of the Engineering Heritage,
1982, Brisbane, 9-12 May

Railway Lattice Girder Bridges in New South Wales

R.E. BEST
Engineer, Maintenance, Bridges and Structures, State Rail Authority of New South Wales
and
D.J. FRASER
Senior Lecturer in Civil Engineering, The University of New South Wales, Sydney

SUMMARY During the period 1880-1890 New South Wales experienced something of a railway mania. In the course of establishing a basic framework for the future railway network, some major river crossings were required; for example, across the Parramatta, Hunter and Murrumbidgee Rivers. In all, twelve crossings were involved and the same style of bridge was chosen for each, namely the iron lattice girder bridge. This paper traces the history of the lattice girder bridge, in particular the railway lattice girder bridges in New South Wales, and discusses details and methods of analysis. The paper also shows what is involved in historical research of works that are a significant part of our engineering heritage.

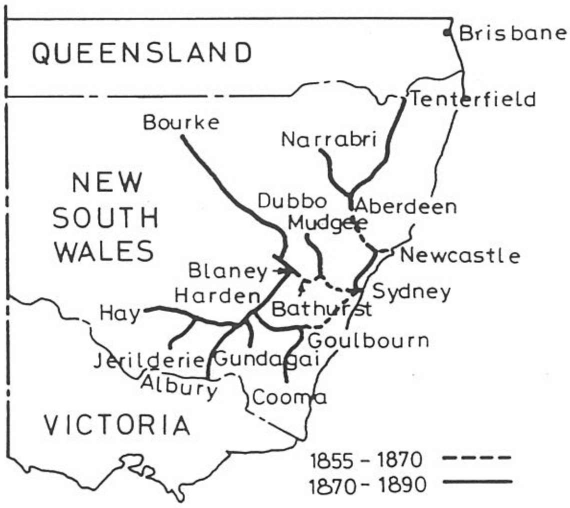
1 INTRODUCTION

Railway service in New South Wales began in 1855 with the opening of the line between Redfern and Granville some 20 km west of Sydney. During the next fifteen years portions of three main lines were built and by 1870 had reached Goulburn in the south, Bathurst in the west and Aberdeen in the north. The 500 km of railways then in use are shown with dashed lines in figure 1(a). Despite the achievement of building the famous Zig-Zag near Lithgow and erecting three major bridges, over the Nepean River at Menangle and at Penrith, and over the Hunter River at Singleton, rate of construction was only modest.

Then came a rapid acceleration. New South Wales experienced its own railway mania and in the next twenty years, 1870-1890, the length of operating lines increased seven-fold to 3500 km. The extent of this growth is shown by the full lines in figure 1(a). A basic framework north, south and west of Sydney had been completed, from which future extensions were to form the current network of 9000 km.

In the course of this twenty-year burst of activity, the railways had to cross four major coastal rivers (Parramatta, Georges, Hunter and Hawkesbury) and six inland rivers (Macquarie, Lachlan, Peel, MacDonald, Murrumbidgee and Murray). In all, fourteen crossings were involved. The Hawkesbury River Bridge, the biggest project, was an American truss design, not a lattice girder bridge, and so will not be dealt with here. A single-lattice girder bridge was built over the Parramatta River at Camellia in 1895 on the Carlingford Line but it was not one of the original twelve double-lattice bridges which are the subject of this paper. The location of these twelve bridges is shown in figure 1(b) and noted in Table I.

During the 1970's three of the original twelve lattice bridges were taken out of service following the construction of modern replacements, and could be destined for recycling as scrap-iron. The others are all past their economic lives and are also scheduled for replacement depending on availability of funds and other priorities. Eventually all will go and with them the tangible evidence of a pioneering era of iron bridge construction important to the colonial history of New South Wales.



(a) Railway network 1890

(b) Location of railway lattice bridges, see also Table I

Figure 1

TABLE I

LINE	No. *	TOWN	RIVER
Main North (Sydney to Tenterfield)	1	Aberdeen	Hunter
	5	Tamworth	Peel
	6	Woolbrook	MacDonald
	11	Ryde	Parramatta
Main South (Sydney to Albury)	3	Wagga Wagga	Murrumbidgee
	8	Albury	Murray
Main West (Sydney to Bourke)	2	Bathurst	Macquarie
	4	Wellington	Macquarie
	7	Dubbo	Macquarie
Narrandera to Jerilderie	9	Narrandera	Murrumbidgee
Illawarra (Sydney to Wollongong)	10	Como	Georges
Blayney to Harden	12	Cowra	Lachlan

* Chronological order of construction

2 THE LATTICE GIRDER BRIDGE

2.1 Origin

Figure 2 shows diagrams of typical lattice girders, a form of construction also referred to as a trellis girder and as a double or multiple Warren girder.

Contrary to the commonly held view that Ithiel Town's timber lattice trusses (1820-1835) were the fore-runner of the metal lattice girders, the latter originated in Europe and Britain (Edwards, 1959). The multiple triangular iron girder/truss was an adaption of the Warren truss developed by Neuville and improved by Captain Warren (Matheson, 1877). Neuville, a Belgian engineer, designed and constructed one of these bridges in 1846 near Ghent. Another, built near Dublin around 1844 is reputedly the first in Britain (Hemans, 1844, Chrimes, 1980).

2.2 Scope of application

During the second half of the nineteenth century, the iron lattice girder became the dominant bridge type (both for road and rail) in Britain, in European countries and in their colonial empires. It was little used in America where the Whipple, Baltimore and Pratt trusses were the most popular types. Because of the widespread use of metal lattice girders, there is an abundance of technical information in contemporary journals and text books. The references in this paper are a sample.

Lattice girders, when properly designed and constructed, proved to be superior to all other non-American types (Baker 1873, Matheson 1877, Merriman and Jacoby 1898) over a wide range of spans, 18m (60 ft) to 90m (300 ft). There were some examples of spans up to 180m (600 ft).

The main advantages of the lattice girder were the saving in weight and its increased stiffness. The open web system enabled the sizes of the "web" members to be readily adjusted to suit changes in shear force, which gave significant savings in web material compared to a plate web girder, Figure 3. At the time, cost differentials made the costs of materials more important than labour costs. When combined with curtailment of the flange (chord, boom) materials , the lattice girder became a very efficient structure.

Increased overall stiffness and stability were achieved by using channel sections for compression web bars rivetted at their intersections with the flat-iron tension members.

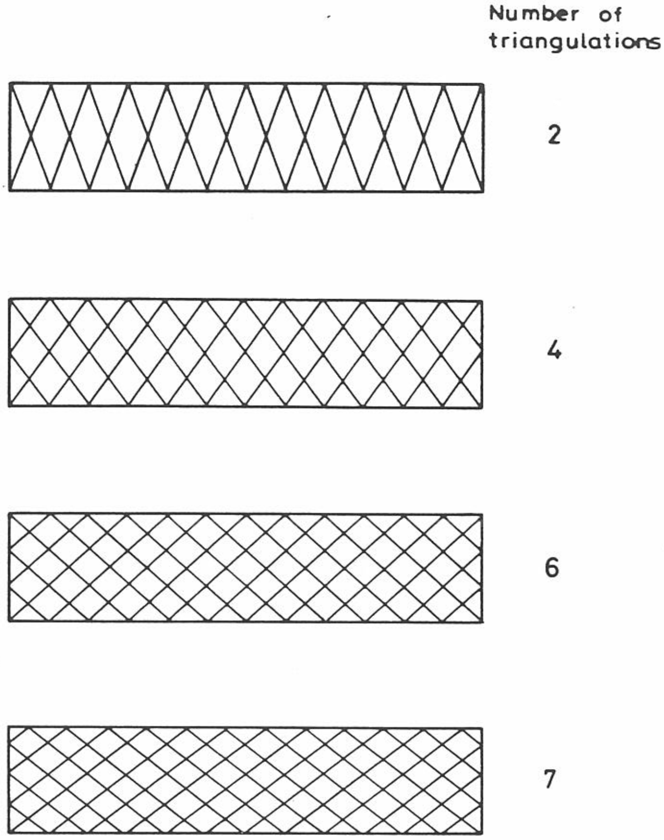


Figure 2 Typical lattice systems

A particularly useful series of papers by Cargill, dealing with iron lattice girders, was published in the Journal of the Franklin Institute, 1863.

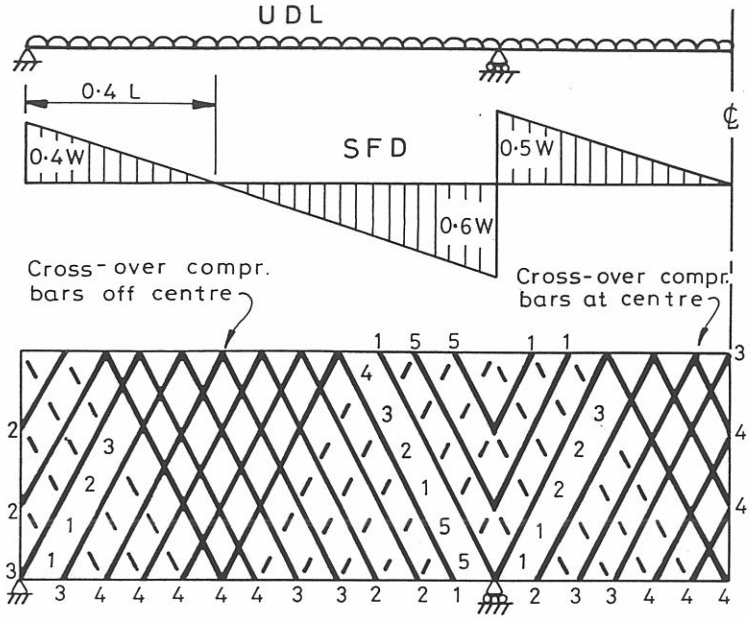
2.3 Some Standard Details

In addition to the basic classification of bridges (beam, arch, suspension), bridges are also classified according to the location of the deck relative to depth of the main girders/trusses, Figure 4. Lattice girders were used in all three situations. The pony bridge was so named because it was not deep enough to allow overhead cross-bracing of the top flanges (Johnson et al, 1894).

The most common form of lattice girder construction is the double-lattice web with multiple triangulations. A double-lattice web has two sets of parallel web bars, Figure 5(a), connected to trough or U-shaped chords. Nearly all lattice girder bridges in New South Wales are of this construction. The single-lattice web, Figure 5(b), is virtually an open-web plate web girder. An example, built in 1895, still exists carrying the railway over the Parramatta River at Camellia, Sydney. The author is not aware of any lattice webs in excess of two.

Multiple-triangulations refers to the number of independent Warren systems within the pattern of intersecting lattice bars. Figure 2 shows the most common numbers of triangulations. All the lattice road bridges in New South Wales have two triangulations hence the term double-Warren truss. Of the twelve railway lattice bridges reported in this paper, six have seven triangulations, four have four triangulations and two have six triangulations.

Without tracing the separate Warren trusses, the number of triangulations can be determined in two ways (Hart 1866), (1) count the number of diamonds and parts thereof in any vertical section and then multiply by two, or (2) take any lattice bar, count the number of intersections and then add one.

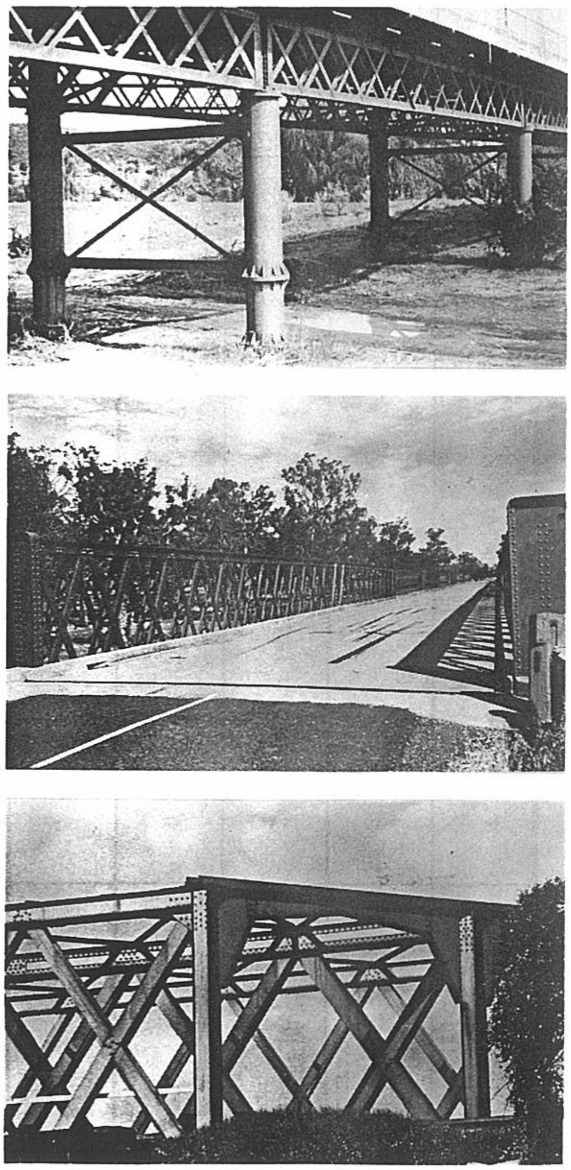


Tension		Compression	
Bars	Area mm^2	Bars	Area mm^2
1	8160	1	11200
2	6400	2	8400
3	5600	3	7680
4	4800	4	6400
5	9760	5	14000

——— Compression bars numbered outside the girder.

– – – – Tension bars numbered inside the girder.

Figure 3 Distribution of lattice bar sizes



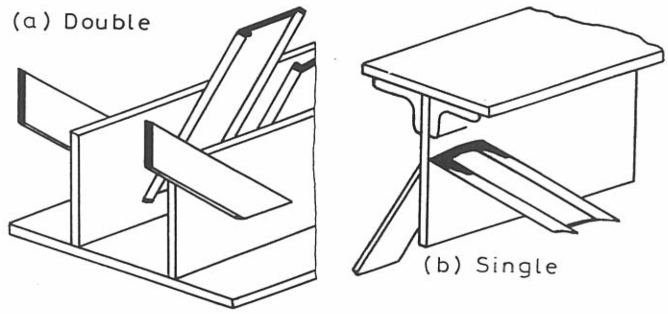


Figure 5 Lattice webs

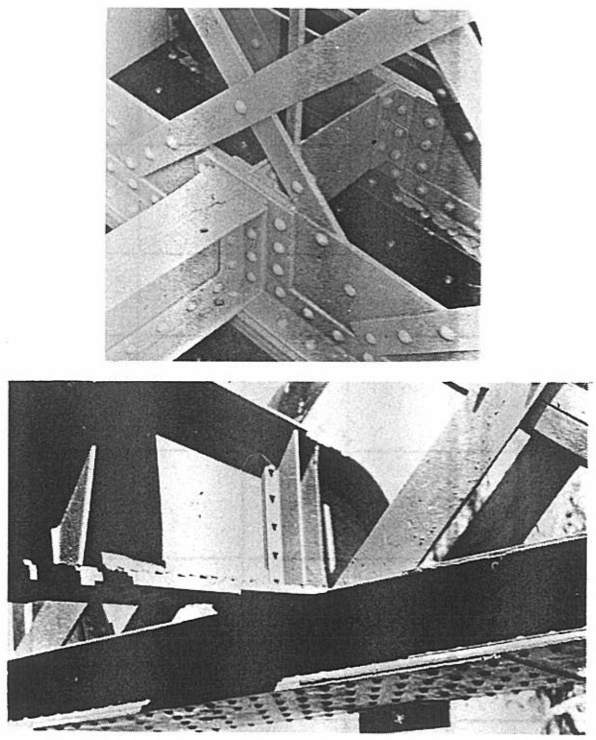


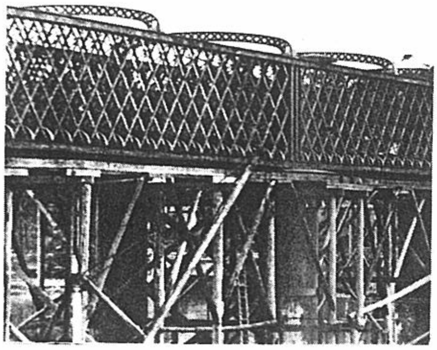
Figure 4 Lattice girder bridges. Deck, pony and Through bridges.

Figure 6 Connections of cross-girder to bottom chords, side and top connections.

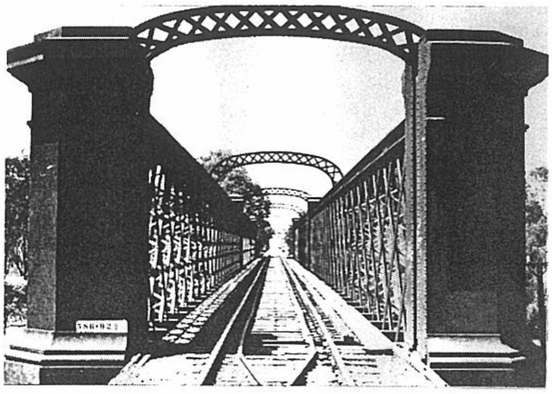
TABLE II

HISTORICAL INFORMATION FOR THE 12 RAILWAY LATTICE BRIDGES IN N.S.W.

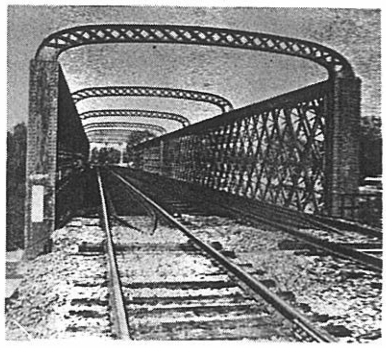
Period	Location River	No of tracks	No of spans 48.5m (159ft)	Contin -uous	No of triangu- lations	Principal Contractor	Supplier of Superstructure (weight in tons)	Erection Sub- contractor	Supplier of Cast Iron cylinders (wgt in tons)	Dates of load tests	Date put into service	Total cost £ cost/m
1870-71	ABERDEEN Hunter	1	3	Yes	7	Amos & Co	Park Gate Iron Co Rotherham, England (580)	Thomas Smithyman	Park Gate Iron Co	14 Feb 1871 19 Feb 1885	17 Apr 1871	£24,840 $341
1875-76	BATHURST Macquarie	1	3	Yes	7	J.S.Cummings. W.Mason (Jnr). Mason and Ellsington	Handyside & Co Derby, England (580)	Thomas Smithyman		8 Mar 1876 7 Jan 1885	4 Apr 1876	£31,130 $426
1879-81	WAGGA WAGGA Murrumbidgee	1	4	Yes	7	Amos & Co	P.W.McLellan Glasgow, Scotland (779)	J.S.Bennett	Stockton Forge Co Stockton-on-Tees (574)	16 Dec 1880 only	23 Jan 1881	£43,490 $446
1879-81	WELLINGTON Macquarie	1	3	Yes	7	W.Watkins	Handyside & Co Derby, England (580)	Thomas Smithyman	Stockton Forge Co (453)	25 Jan 1881 9 Jan 1885	1 Feb 1881	£45,450 $485
1881-82	TAMWORTH Peel	1	1	No	7	A & R Amos	J.O&C.E.Brettell Worcester, England (190)	J.S.Bennett	Stockton Forge Co (155)	16 Nov 1881 20 Feb 1885	9 Jan 1882	£9,550 $420
1881-82	WOOLBROOK MacDonald	1	1	No	7	A & R Amos	J.O&C.E.Brettell Worcester, England (190)	J.S.Bennett	Brick Abutments	20 Feb 1885	2 Aug 1882	£9,550 $420
1883-84	DUBBO Macquarie	1	3	Yes	4	A & R Amos	Cochrane & Co Middlesborough, England (580)	Benjamin Barnes	Cochrane & Co (741)	23 Apr1884	May 1884	£49,210 $525
1883-84	ALBURY Murray	2	2	Yes	6	A.Frew	Westwood, Baillie (603)	J.S.Bennett	Stockton Forge Co (509)	24 Sep 1884	18 Oct 1884	£32,520 $669 2 tracks
1884-85	NARRANDERA Murrumbidgee	1	2	Yes	4	Halliday & Owen	Westwood, Baillie (396)		Stockton Forge Co (370)	4 May 1885	May 1885	£22,170 $459
1884-85	COMO Georges	1	6	Yes 2x3	4	C & E Miller	Cochrane & Co Middlesborough, England (1101)		Stockton Forge Co (1077)	19 Jan 1886	26 Dec 1885	£66,140 $453
1885-86	RYDE Parramatta	2	6	Yes 2x3	6	Amos Bros	Handyside & Co Derby, England (1508)		Stockton Forge Co (862)	10 Sep 1886	17 Sep 1886	£69,000 $472 2 tracks
1886-87	COWRA Lachlan	1	3	Yes	4	Fishburn & Co	A.Lecoq Halle, Belgium (540)	D & W Robertson	Stockton Forge Co (982)	2 Sep 1887	2 Sep 1887	£52,000 $459



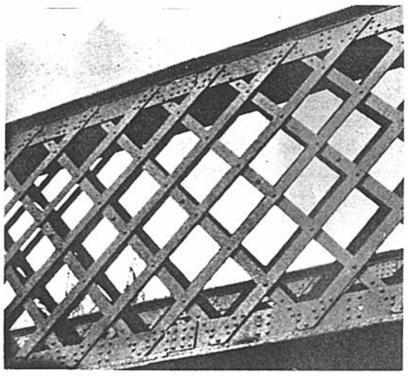
Construction



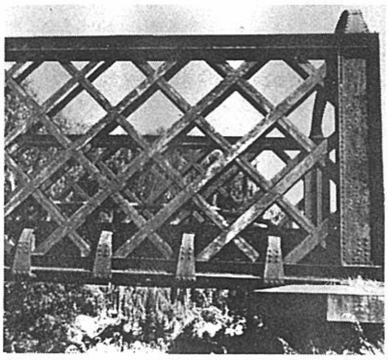
Single track bridge



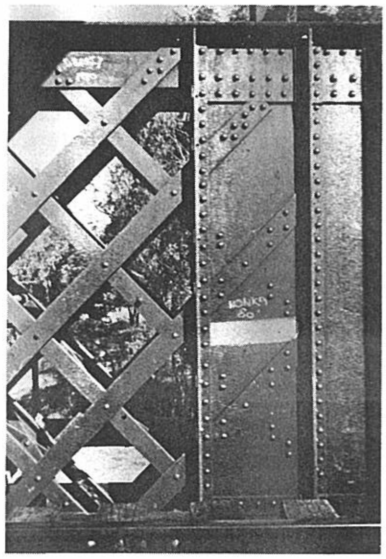
Double track bridge



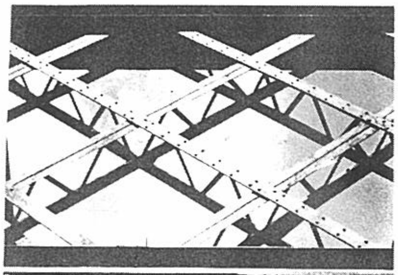
7 triangulations



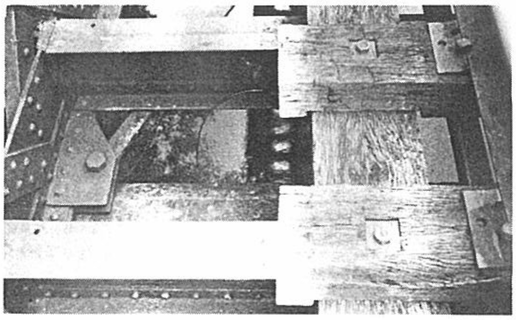
6 triangulations



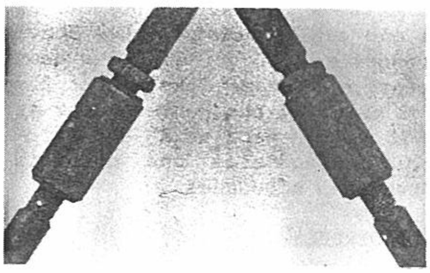
End post



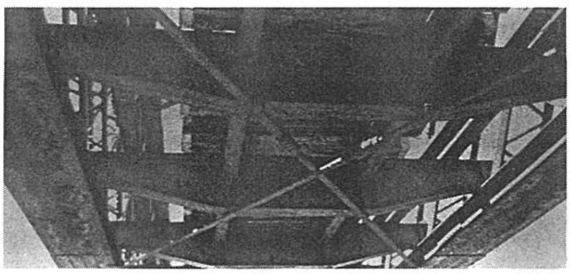
Double-lattice web,4 triangulations



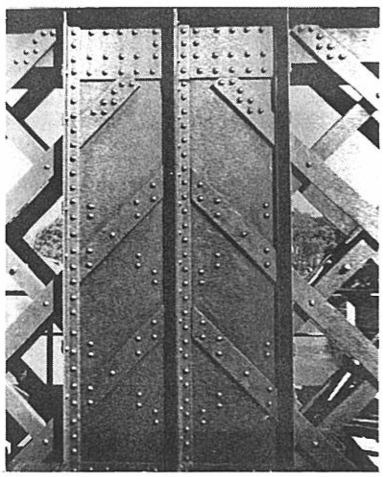
Track on longitudinal timbers



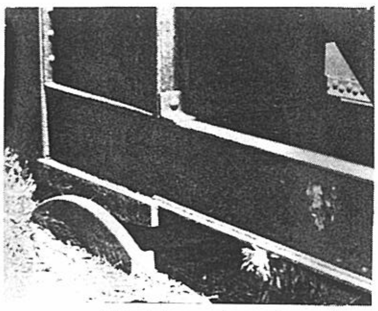
Turnbuckles in bracing



Deck system,improved design



Post at continuous support



Fixed rocker bearing

Roller bearing

Figure 7 Typical details of railway lattice bridges.

Directly related to the number of triangulations is the method of connecting the cross-girders to the main lattice girders, Figure 6. The spacing of the lattice bars is a critical factor (Cargill 1863). Framing the cross-girder into the side of the open trough-shaped bottom chord, Figure 6(a), causes twisting of a section that is structurally inefficient in torsion. The remedy is dealt with later in respect to the twelve railway lattice bridges. Supporting the cross-girders on top of the bottom chord, Figure 6(b), is structurally superior and simpler in detail.

3 RAILWAY LATTICE BRIDGES IN NEW SOUTH WALES

Table II shows a summary of the principal items of information concerning the twelve lattice bridges built for the New South Wales Government Railways between 1870 and 1887. Within the twelve there are only three different designs

1. The first six bridges, built for single lines of railway, have longitudinal timbers supporting the track. The cross-girders are connected to the sides of the bottom chords and the main girders have seven triangulations.
2. Four of the second six bridges were also built for single track and were an improved design. The track is supported by longitudinal steel beams which in turn are supported by cross-girders that rest on top of the bottom chords. The main girders still have double-lattice webs but the triangulations have been reduced to four. These bridges have a more open and lighter appearance.
3. The remaining two bridges, at Albury and Ryde, were built for double track and incorporate all the improved features. The main girders are much deeper and use six triangulations.

All were major bridges of their day, and contemporary newspapers (see references) carried regular reports about them during construction. They were all relatively expensive bridges due mainly to the length of construction time, between one year and 18 months. Their final costs at approximately £75 per linear foot is equivalent to around $15 000 per metre today, based on a labourer's wage of 10/- per day in the 1880's. Modern technology and construction methods enable replacement bridges of similar size to be built for half this amount. Figure 7 shows the technical details of these railway lattice bridges.

All twelve bridges have spans of 48.5m (159 ft) and a common feature of ten of them is the use of continuous spans, mainly in groups of three. The bridges at Albury and Narrandera are two-span continuous and the Wagga bridge has four continuous spans. Only two single span bridges were built, at Tamworth over the Peel River in 1881 and at Woolbrook over the MacDonald River in 1882. The latter is the only bridge not to have cast-iron cylindrical piers. The shallow depth to sound rock enabled solid brick abutments to be used.

When the original sets of working drawings were examined and site inspections made, it became clear that all the bridges incorporated the flexibility of distributing web material,as noted earlier. The sizes of lattice bars at the ends of each spans are much larger than those in the central region of each span, Figure 3, which is consistent with the changes in shear force. In the case of continuous bridges, the distribution of web material matches the different values of shear at each end of the outer spans, and also the shift of the point of zero shear towards the outer supports, figure 3.

Despite the apparent completeness of this dossier there are some questions still to be answered:

- Why use lattice girders? Were other types of bridges considered? Who designed the bridges? Why use 48.5m (159 ft) spans? Why use the same span at all sites?

The authors have not yet found specific statements about these matters, but the following answers are quite plausible.

1. Since lattice girders were the dominant type of bridge in Britain and its colonies, then its choice could be classed as routine, probably inevitable. As late as 1890, the Commissioner and Engineer-in-Chief for Roads and Bridges, Robert Hickson, considered "lattice girders to be the best type of bridge" (Cowra Bridge Report 1890).
2. There is only a faint possibility that other bridge types were considered, despite the fact that two "American style" Whipple trusses were built in New South Wales during the period under review. A report on these two bridges, the road bridge at Nowra 1878-81 and the rail bridge at Lewisham 1885-86, has been presented elsewhere (Fraser 1981). One span of the Nowra bridge was on display at the 1881 International Exhibition in Sydney. The Judges concluded "unless under peculiar circumstances,the lattice type of bridge is preferable for both railway and road in this Colony",(Main Roads,1971).
3. All the working drawings have the stamp of John Fowler, the eminent British consulting engineer, who was Agent for the New South Wales Government. Although some original design work may have been carried out by John Whitton (Engineer-in-Chief, NSWGR) or his staff, it seems most likely that responsibility for design and preparation of drawings rested mainly with John Fowler.
4. The technical references show that a span of 48.5m (159 ft)was within the economic range for lattice girder bridges. Since the initial six railway bridges used longitudinal timbers over 0.91m (3 ft) spans to support the track, then any chosen span had to be divisible by three. For the later bridges, with steel stringers over spans of 1.3m (5'8") and 2.26m (7'5"), the 48.5m span seems irrelevant.
5. The years 1870-1890 were a hectic period of railway expansion and construction in New South Wales. All the bridges were fabricated overseas (Table II). Therefore, it seems likely that the original design for crossing the Hunter River at Aberdeen, 1870-1871, was adopted as a "standard" in order to save design time and maintain delivery and construction schedules.

4 ANALYSIS OF LATTICE GIRDERS

The contemporary technical literature contains a number of methods for the analysis of lattice girders. These methods may be classified in two ways, the use of beam analogy and the use of truss theory. Only one from each class will be dealt with here, Rankine (1856, 1882) and Warren (1894). The lattice girder shown in Figure 8(a) will be used to briefly explain the two methods and their results will be checked using a modern computer-oriented method.

4.1 Beam Analogy

The lattice girder is visualised as a beam with an open rather than a solid web. Elementary statics of beams in bending is then applied to calculate the bending moments, M, and shear forces, S, at sections mid-way between the load joints, Figure 8(b). From the conditions of internal equilibrium $C_f = T_f = M/D$ and $C_w = T_w = S/(4\sin\theta)$. If a shear force diagram and bending moment diagram are used, the analysis need only occupy one standard calculation sheet.

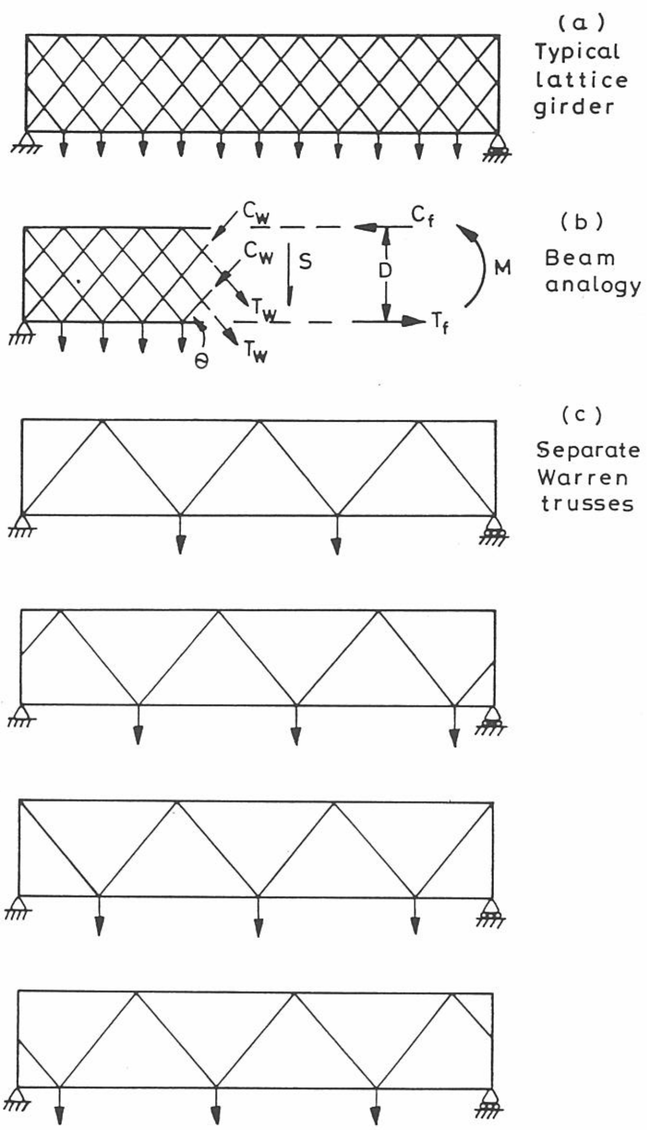


Figure 8 Analysis of lattice girders

4.2 Truss Theory

The lattice girder is visualised as a series of overlapping Warren trusses, equal to the number of triangulations. These trusses are analysed separately, Figure 8(c), and the results added together. The calculations would normally take more sheets than the beam analogy method, however, Prof. Warren does show how the analysis by truss theory can be presented in a compact table.

4.3 Computer Analysis

The previous methods have three sources of error -

1. All lattice bars are assumed to be pin-connected to the chord members, whereas the amount of rivetting suggests a relatively stiff joint which could generate secondary bending in the web members and in the chords.

2. The joints between chord members and posts are also assumed to be pins whereas the substantial rivetting would approximate a rigid joint.

3. The rivetting of the lattice bars at their intersections is ignored, each bar being considered as a separate member from its top to bottom chord joints. The reality of the connections renders the web highly indeterminate and must cause some redistribution of the web forces. Modern computer methods enable all these factors to be taken into account. For reasons of space, none of the details are given here. The results from all three methods are in reasonably good agreement for the member axial forces. However, the secondary bending moments in the chords are significant which could lead to an unsatisfactory level of combined stress.

5 THE RESEARCH

The brevity and ordered nature of this paper is completely opposite the realities of the research effort. Indeed, if the paper and its presentation are taken as a unit measure of effort then the background effort was in the order of one hundred-fold.

Research began in early 1980 at the Archives Office, State Rail Authority of New South Wales (SRA), with an examination of some original drawings, historical notes, photographs (contemporary and recent), Annual Reports 1870-1890, and most important, a copy of the Railway Bridge Inquiry Report 1884-1886.

The setting up of this Inquiry by the New South Wales Government was the result of personal animosity between the Engineer-in-Chief, John Whitton, in charge of railway construction and the Engineer for Existing Lines, George Cowdery, in charge of railway maintenance. Cowdery planned to have repairs and other work carried out on the six earliest iron lattice bridges and he requested plans and data from Whitton. The request was refused on the grounds that the bridges had been soundly constructed and the nature of the repairs and their effect upon the safety of the bridges had been exaggerated. Cowdery appealed to the Minister for Public Works who was presented with conflicting opinions, technical and personal, from both men. In order to resolve the matter, the Minister set up a Select Committee to inquire into the safety of the iron lattice bridges and of certain timber viaducts. The Committee came to some face-saving conclusions for George Cowdery and recommended some minor repairs, such as replacing some loose rivets, plus the exchange of plans and other technical information. However, the technical opinion of John Whitton and the safety of the bridges were vindicated then, and during the next one hundred years of service, by carrying loads well in excess of the original design.

The final report of the Select Committee contained much valuable information about lattice girder bridges, particularly technical, because Professor Warren from Sydney University and Professor Kernot from Melbourne University were members of the Committee. The results of their analyses of the single span and of the continuous span lattice girder bridges are contained in the Appendix and the Special Reports.

Despite this good start to the historical research, only about half the information in Table II was obtained and then mainly about the first six bridges. Most of the remaining information was obtained from a slow, patient search of contemporary newspapers (see references) at the State Library, Sydney, principally the Sydney Morning Herald. The most daunting feature of this work was the general lack of indexes.

The whole process would rival any detective work, with its mounting volume of news items and dates, sometimes confusing the search, but mostly clarifying matters. For example, the bridges at Wagga

Wagga, Dubbo and Albury were completed almost a year after the railway lines were opened for service. The initial river crossings were all carried on temporary timber viaducts.

Enquiries were not confined to Australia. Some relevant information was obtained from sources in England, particularly the library of the Institution of Civil Engineers, London (Chrimes 1980).

Concurrent with a search of old newspapers and archive records was a search of old calculation books and reports dealing with colonial railway bridges. These documents are held by the Way and Works Branch of the SRA, and were made available by the co-author, Ross Best.

Each of the twelve railway lattice bridges was visited, photographed in detail and many measurements taken in order to clarify data shown on the faded and sometimes damaged original drawings.

All this material forms a large dossier of research notes that are presently the subject of a comprehensive report by the authors. The report will be held at the SRA Archives Office.

6 ENGINEERING HERITAGE AND PRESERVATION

The twelve lattice girder bridges in New South Wales represent the first major programme of iron bridge construction in the colony and they were vital components of the rapidly expanding railway network.

The bridges crossed two wide coastal rivers and there were ten crossings of the inland rivers, rivers capable of large and violent floods, and yet all bridges have survived nearly 100 years and more.

Three of the bridges, at Aberdeen, Como and Ryde, no longer carry rail traffic and are destined to be removed, probably as scrap iron. However, although they do not meet modern railway requirements they are suitable for re-use in less demanding situations. For example, the 1882 lattice bridge over the Iron Cove, Sydney, now serves as a road bridge near Forbes and has an appropriate commemorative plaque attached.

All the bridges have served the railway system and the State well through a century of changing and increasing demand. They have significant merit in terms of engineering heritage.

7 CONCLUSION

This paper has presented a case study of the historical research of a group of lattice girder bridges built in the colonial years 1870-1890 in New South Wales.

The investigation was a major project extending for nearly two years. It highlighted two essential characteristics of a successful researcher, patience and persistence. Not all the information about the bridges was in the obvious place and there were consequent periods of frustration as the investigation appeared to founder. However, these were relieved by elation when the relevant information was found.

The paper summarises the results of the research and has indicated the nature and extent of the research effort involved.

8 ACKNOWLEDGEMENTS

The authors gratefully acknowledge the valuable cooperation of John Forsythe, Archives Officer, State Rail Authority of New South Wales, and of the staffs at the State and Mitchell libraries.

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The Reconstruction of the Wagga Viaduct

W.M. SHELLSHEAR, F.I.E.Aust.*

1 EARLY HISTORY

The English Journal "The Engineer", in its issue of 13 December 1878, reported:-

> "A further extension of the Great Southern Railway of NSW from Junee to North Wagga, opened on 3 September 1878, is 17 miles 61 chains in length, making a total distance of 304 miles 22 chains from Sydney".

The section described was part of A. and R. Amos's contract awarded in September 1874 for construction of the Southern line from Cootamundra to North Wagga (renamed Bomen in 1882). In January 1878 Amos's contract was extended to South Wagga and "Engineering" had this to say about it:-

> "Messrs Amos Bros have a short length of 4½ miles in hand on the Southern line, namely from North Wagga across the Murrumbidgee into South Wagga. The bridge across the Murrumbidgee will be the longest and most expensive in Australia".

Amos's contract comprised the supply and erection of an iron bridge spanning the Murrumbidgee River, which, at this point, flows through a fertile valley, and the carrying of the railway over the river flats on a series of viaducts. There were six viaducts in all; the respective number of spans in each being 113,66,4,72,56 and 5, or a total of 316 viaduct spans. The first four were on the north side of the river and the remaining two on the south side. The spans were 29ft 6in each, so that the aggregate length of the viaduct spans exceeded 1 3/4 miles. Varying lengths of embankment separated the viaduct sections. This large number of openings was found necessary as, during heavy floods, the river overflowed its banks and submerged the flats to a depth of 10 to 12ft for a width of up to 2½ miles.

Although the lattice girder bridge was included in the Amos contract, the steelwork was supplied by McClellan of Glasgow and the erection carried out by J.S. Bennet on behalf of A. and R. Amos.

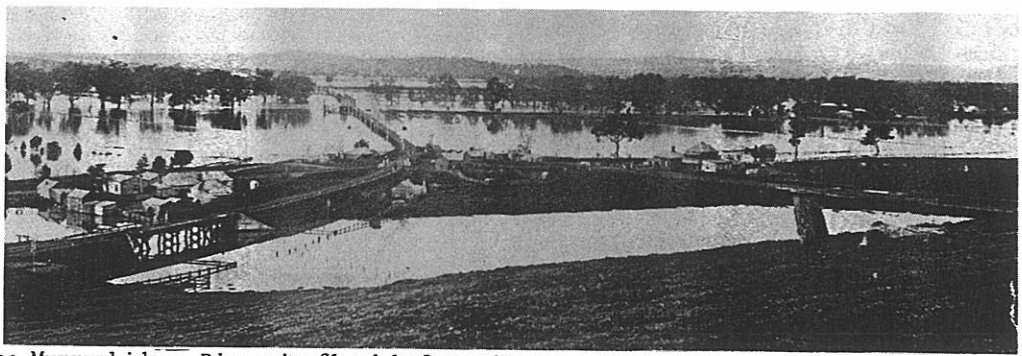
The iron bridge, which still exists, consists of two lattice main girders continuous over four openings, each having a clear span of 150ft, with a centre distance of piers of 159ft. The lattice girders are 12ft 1in high, and plate web cross girders are spaced at 3ft centres.

A light lattice overhead bracing girder, rivetted to the tops of the lattice girders was provided at the piers and at mid-span.

Bridge piers are cast iron cylinders 9ft in diameter filled with concrete and are in pairs connected by wrought iron diagonal bracing. The tops of the cylinders were placed 5ft 5in above the 1870 flood level.

Details of the timber viaducts as constructed by A. and R. Amos, are shown in the accompanying drawing. The drawing shows a pier mounted on a concrete sill as most of them were, but about 20% were seated on driven piles. Almost 1300 piles were driven, some as deep as 57ft into the ground.

In view of the extensive nature of the work involved in Amos's contract extension, and of the time likely to be taken, the contractors were authorised to construct a temporary low-level railway along the river flats to cross the main river channel by 35 - 18ft



The Murrumbidgee River in flood before the re-construction of the southern section of the viaduct was completed.

(Paper G1202 submitted on 1 June, 1986.)

timber openings, 26ft above normal river level. By this means, trains commenced to run regularly into South Wagga on 1 September 1879. The temporary crossing was severely damaged by flood waters shortly after its completion, causing interruption to traffic. The road bed of this first temporary crossing of the Murrumbidgee may still be seen on the eastern side of the main line.

However, when work on the viaduct was commenced in 1876 great difficulty was experienced in obtaining the enormous quantities of iron bark timber required for the structure in the short space of time allowed in the contract for its erection, necessitating the use of some inferior timber which soon decayed, and constant repairs and renewals were subsequently required.

The amounts of timber involved in the original viaduct structures were:-

Girders and corbels	88,000 cu ft
Transoms and headstocks	21,000 " "
Bracing, etc	15,000 " "
3" Decking	9,800 " "
Piling	30,000 lin ft.

On the completion of the Amos contract the line was opened from North Wagga, through South Wagga, to Gerogery on 1 September 1880. Although the Amos contract terminated at South Wagga (later re-named Wagga) a second contract had been awarded in February 1878 concurrently with Amos's contract extension, for construction of the line from Wagga to Albury, and work had been proceeding well on this contract. The contractors for the Wagga-Albury section were Messrs Cornwell, Mixner and Co.

2 ROYAL COMMISSION

It would appear that, within three years of the opening of the line through South Wagga, maintenance of the timber viaduct had become a matter of some concern, particularly to George Cowdery, the Engineer for Existing Lines. Cowdery complained that the girders were not sufficiently strong or rigid to prevent an engine jumping when going at high speed, and claimed that engine drivers had also complained of this jumping. Cowdery had already placed props under some of the girders which he had found defective, and had placed a speed restriction of 16 mph for trains crossing the viaduct. On the other hand John Whitton, Engineer in Chief, who also held the portfolio of design and construction, took strong exception to Cowdery's criticism of the viaduct and a somewhat acrimonious situation developed between these two officers. Cowdery, in the performance of his duties, considered it necessary, not only to provide additional support to some of the viaduct timbers, but also to renew what he considered to be loose rivets and defective work in the iron bridge. Being responsible for the safety of these structures, he did not refer to Whitton for his advice on the matter and considered himself competent to deal with the subject without such reference. He, however, applied to Whitton for drawings and plans of the various structures but these Whitton, for reasons best known to himself, refused to supply.

Whitton also condemned Cowdery for the re-rivetting of the iron bridges. Cowdery however, assured the Railway Commissioners that the bridges were very defective. Asked by the Commissioners to comment on Cowdery's claims Whitton said the bridges were in good condition and that "no better bridges with regard to the material and workmanship, were ever built".

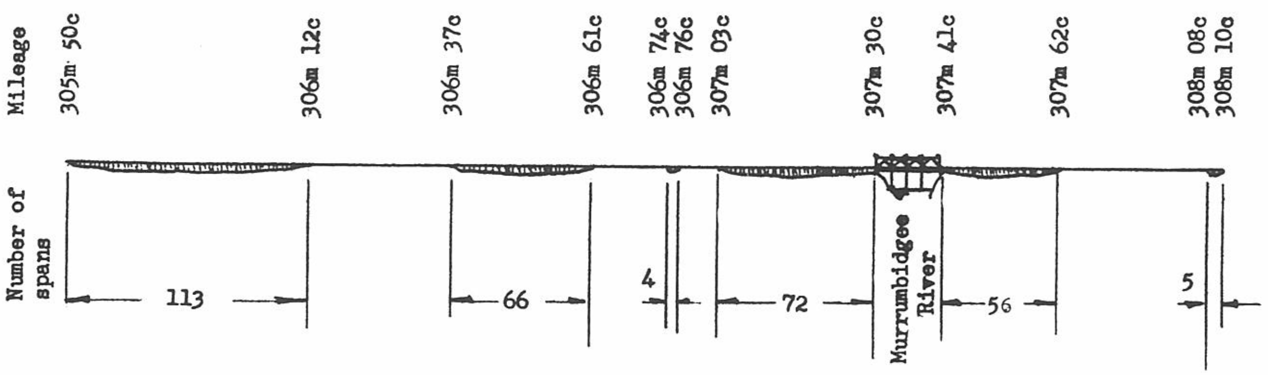
With regard to the timber in the viaduct Whitton had to concede "the timber was to all appearances sound when put in, and that every care was taken to have the work properly carried out, but that the dry rot which had made its appearance some time after the completion of the work was accelerated to a great extent by the timber having been cut when the sap was up instead of during the winter months" and that "the timber supports, having a large margin of strength, no danger need be apprehended if the progress of the dry rot be carefully watched".

This difference of opinion led to a personal attack on one side and recrimination on the other. Cowdery regarded Whitton's statements as an insult to him and his officers. At this point, in order to arrive at a sound decision in the dispute, the Minister for Public Works, one F.A. Wright, feeling himself unable to deal with the technical matters involved, and to allay any feelings of alarm in the minds of the travelling public as to the stability of the bridges and viaduct, determined to refer the subject for an enquiry by a Commission of Experts.

Accordingly, a Royal Commission was set up on 23 April 1884 "to enquire into the stability of certain iron bridges and of the timber approaches to the bridge over the Murrumbidgee River to Wagga Wagga".

The members of the Royal Commission were:-

- G.A. Morell (President) Civil Engineer
- W.C. Kernott M.A. Professor of Engineering, Melbourne University
- W.H. Warren A.M.I.C.E. Professor of Engineering, Sydney University
- W.McD. Courtney M.I.C.E., M.I.M.E. Civil Engineer
- Owen Blackett.



Elevation Showing Location of Viaduct Sections

W.H. Warren and W.C. Kernott became very distinguished leaders of their profession in later years, and in fact, a W.H. Warren Prize is still awarded annually by the Institution of Engineers, Australia to engineers who have made a significant contribution to the science and practice of engineering in Australia.

The members of the Royal Commission in their Progress Report of 25 March 1885, alluded briefly to the differences of opinion or the want of harmony existing between the two great branches of the railway department with regard to the construction and maintenance of railway bridges and viaducts.

During the course of the Commission's investigation, which lasted from April 1884 to August 1885, a very detailed investigation into the adequacy of the viaduct's design was carried out, both on the viaduct itself and on experimental sections made up in the railway yards at Clyde for testing under load. All these tests appeared to confirm Whitton's claim that the viaduct design was adequate and safe. As might have been expected, Whitton's evidence before the Commission carried more weight than Cowdery's, and in the Commission's Final Report of 22 August 1885 we find the following comments and summing up concerning the Wagga viaduct:

> "Taking the average life of a bridge constructed with good timber and properly maintained to be 25 years, the yearly renewal of the material will be about 4% of the whole. From the analysis of our timber inspection, we find, however, that owing to the defects stated to exist in the piles of the Wagga viaduct, nearly the whole of the piers may have to be renewed within 20 years, whereas the superstructure, being ironbark, may last over 25 years."

And regarding Cowdery's speed restriction the Commission reported:-

> "We tested accurately the motion of the beams and trestles in every direction and found very little movement at any speed. Observations were also taken from an ordinary passenger carriage and from the overhanging platform of a bogie car. As a final test we rode on the engines when running at a speed exceeding 30 mph and found but little difference when running over the viaduct or on the embankments. The viaduct is therefore sufficiently stiff for the heaviest traffic that passes over it. We do not therefore see any reason why the ordinary speed of trains passing over the viaduct should be reduced, and we are of the opinion that, with proper maintenance no danger need be apprehended on account of the speed."

2 RECONSTRUCTION

Bear in mind that this report was issued in 1885 - yet despite its assurances that the viaduct piers would be good until 1905 and the superstructure until at least 1910, we find that a decision was taken only eleven years after the issue of the Commission's report to replace the whole 1 3/4 miles of timber viaduct with steel structures. It appears repairs had become very expensive, and, despite the assurances of the Royal Commissioners, speed reductions had to be re-imposed, which caused great inconvenience. As early as 1892 'P' class locomotives had been allowed to cross the viaduct, but due to the rapid deterioration of the timbers this permission was soon afterwards withdrawn. By 1896 also, the increasing loads of trains made it desirable to use more powerful locomotives than those of the 'D and 'B' classes.

Work commenced on the reconstruction of the viaducts in March 1897 and consisted basically of the complete removal of the existing timber girders and piers and their replacement of steel plate web girders and steel piers erected on concrete cylindrical bases excavated to sound material. The design and construction methods employed were such that the entire replacement of the 1 3/4 miles of timber viaducts was able to be carried out during ordinary working hours, on week-days, without interference to traffic - a truly remarkable achievement. It is also of interest to note that by changes near the abutments of the various viaduct sections, the total number of spans was reduced from 316 to 310.

The second drawing shows typical details of the structures which replaced the old viaducts. Note that the span from pier to pier is the same as before. The new concrete bases were placed about 10ft away from the old wooden piers so as not to interfere with the existing structures, while the bases, some of which were excavated to depths of up to 15ft, were being poured. It is believed as many as four separate contracts were awarded for different sections of the work which took over four years to complete.

The new abutments at the ends of each embankment section were of concrete and at every tenth span a concrete pier was substituted for the steel pier to ensure longitudinal stability. These features are clearly shown in the photographs. Preliminary work consisted of the laying of temporary sidings at ground level along the eastern side of the line, using the formation of Amos's early temporary low-level railway between Bomen and Wagga Wagga. Two travelling cranes, each capable of lifting 10 tons were made up for material handling and for

The lattice girder bridge prior to reconstruction of the viaducts. Note speed restriction lamp at approach to bridge.

The first stage - steel piers constructed on concrete footings under existing timber girders.

lowering the made-up steel girder sections into place. Old tender frames were used for the framework of the travelling cranes, the hand-operated winches used being provided by the locomotive department.

Motive power for the travelling cranes was provided as required by two 'A' (93) class 0-6-0 locomotives.

Advantage was taken of the dry seasons to put in the concrete foundations as rapidly as possible. The steel piers were then erected on these bases under the wooden girders before interfering with the existing structures. The procedure for replacement of the wooden girders and piers with the steelwork, and the manner in which it was carried out cannot be better described than by the account given in "The New South Wales Railway Budget" of 21 December 1899, which reported:-

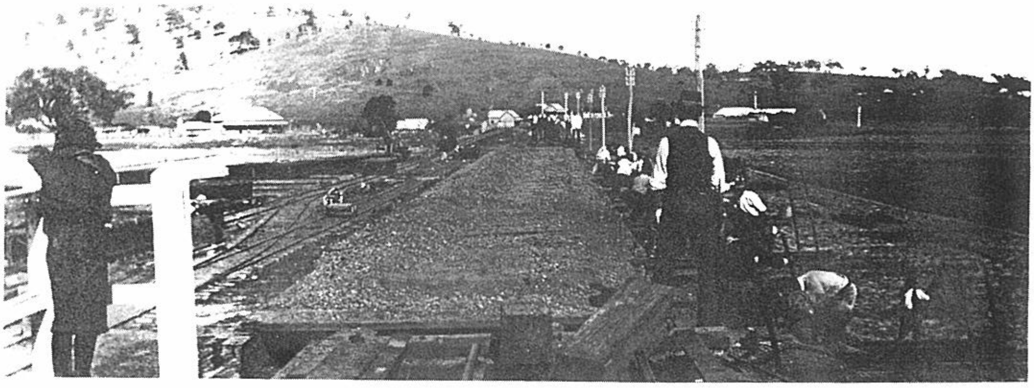
"When all is ready the Divisional Engineer decides how many spans of the old superstructure it is advisable to remove, and then commences preparations for the demolition of the old work and the erection of the new. At the point determined on a cut is made, and then so much of the old work as is to be removed is jacked up, and a rail inserted between the corbel and headstocks to be used as skids, and on these "trip jacks" are fixed for the purpose of forcing over the old superstructure.

A day is chosen when the traffic requirements will give most time for carrying out the work and when the last train has passed, men disconnect the rails and remove the sleepers. At each of the jacks two men are placed, and at a given signal all commence work together and the great mass of timber superstructure, about 300ft long and weighing over 300 tons, begins to move; after the jacks have run out a "fleet" (sic) is ordered and by a simple device the jacks are again brought up to their work, the signal is again given and so on until the whole length gets to its centre and begins to topple, then with a final and simultaneous push on all the jacks, the whole mass is sent over. The side touches the ground first and makes a tremendous thud, and then again as the whole length completely capsizes. The shaking up the timber work has received by the fall greatly facilitates the taking apart of the work. Whilst this work has been proceeding one of the cranes has already approached the gap with one complete span of the steelwork swinging from its jib and this is lowered into place. The crane then returns for another span, and in the interval the track is advanced over the new span so that the crane can approach the reduced gap and so on until complete".

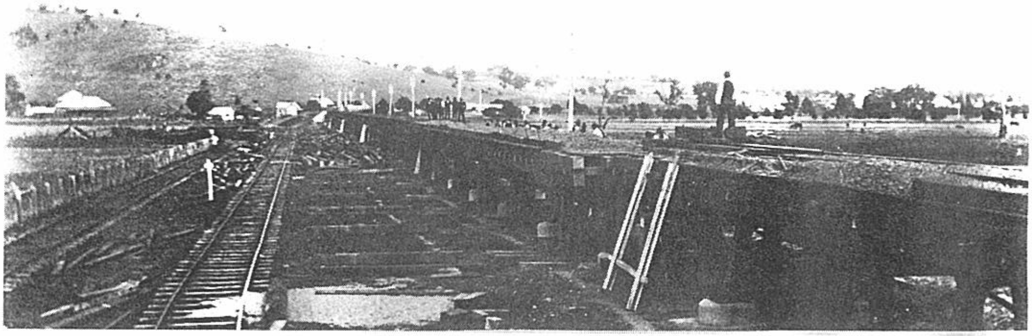
An even more colourful account occurs in the 20 October 1897 of the same journal:

"Recently, by means of a very simple process, a further length of 170ft of the viaduct was cut out and turned over quite clear of the line in a few minutes. The intervening gap which was bridged by six spans of the specially made steel girders, was restored in 2 hours and 37 minutes. This was considered to be an excellent achievement, as traffic on the railway was not in any way interrupted. When the Sydney mail train passed, about 9.20 am, a ballast train which was in waiting at the Wagga station steamed down to Bomen, and the navvies and carpenters set out to remove the old spans at 9.38 am. In nine minutes the lengths were taken out and turned bodily to one side. By 10.14 am the first of the six steel spans was brought by travelling

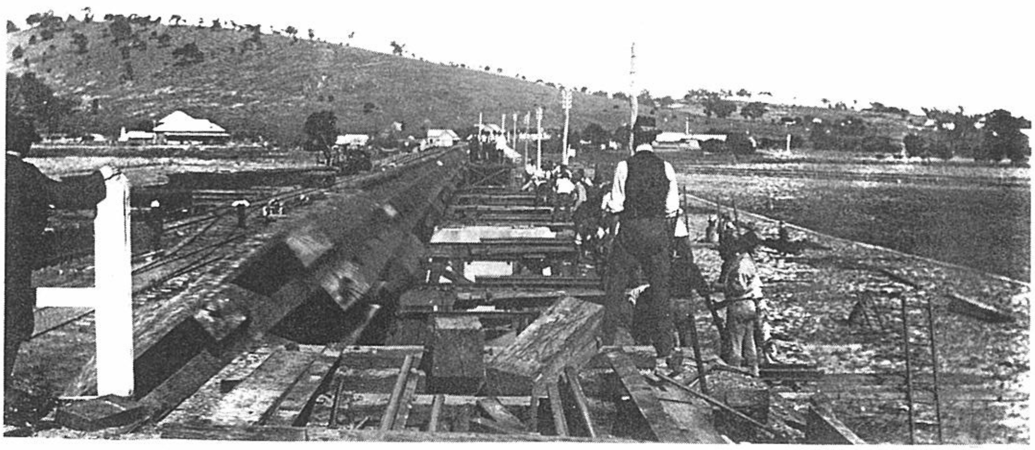
Rails and sleepers removed from the length of deck to be demolished. Deck has also been jacked up to permit placing of slide rails between corbels and headstocks over each timber pier.



Jacking across of the section to be removed has commenced. Decking has moved across about 2 ft. Note also steel girder stockpile on the left and temporary trackage at ground level.



The same operation as seen from the ground. Note close spacing of round wooden sleepers on temporary track at ground level.

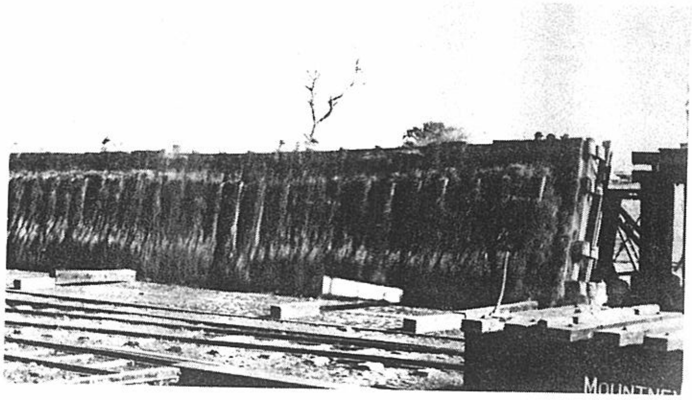


Deck teetering and about to fall.

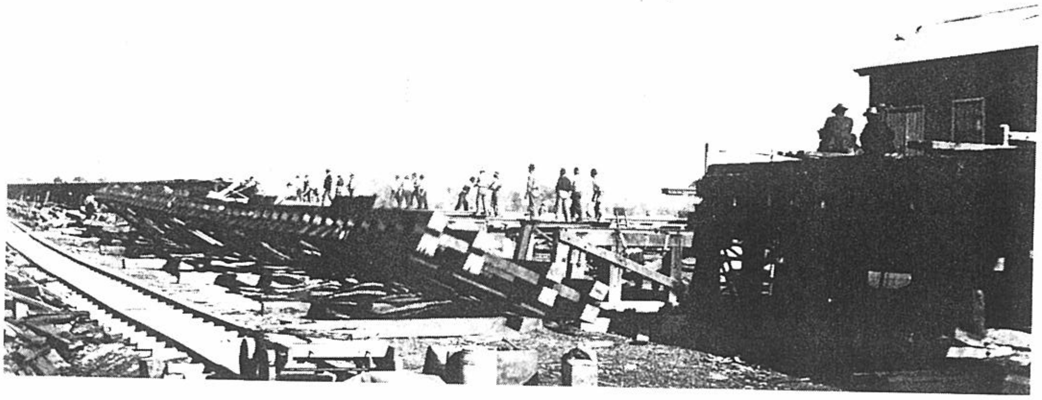
crane from Bomen and deposited in its allotted position. So the work proceeds. By one minute past noon the sixth span was screwed down. A quarter of an hour later the road was clear again for all trains between Sydney and Melbourne. The work is of a most interesting character, every step being carried out with such method that not a hitch occurs. The men don't botch their work".

Steel fabrication was carried out under four separate contracts. Photographic evidence indicated that the fourth of these was awarded to Mountney and Co. of Pyrmont. Possibly some, if not all, of the other three contracts was also carried out by Mountney, but the author is unable to confirm this.

Altogether the work took just over four years to complete and was completed under the departmental estimate of 50,000 pounds. This is a somewhat staggering result when compared with the original cost of the timber viaduct of approximately 70,000 pounds. However, in commenting on the final cost the New South Wales Railway Budget points out that this was a fortunate outcome of the cheapening of bridge construction during the years when reconstruction took place. It commented also that if the viaducts had been made of steel in the first instance the cost would at least have been double

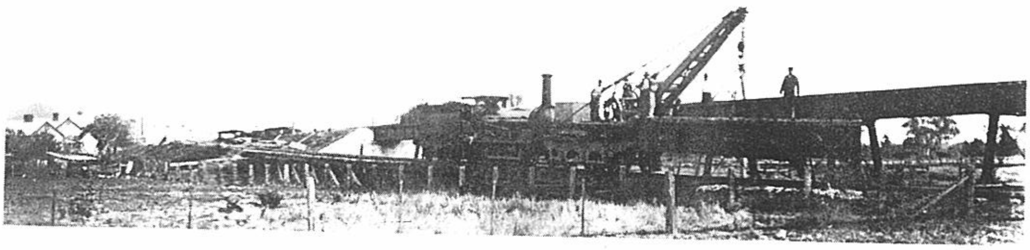


Edge of deck hits ground and ballast cascades down.

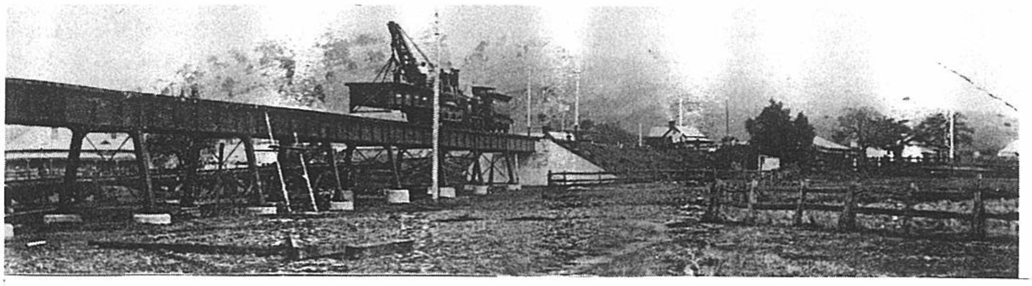


Deck about to fall flat on ground. Building on right is the Wagga water supply pump house.

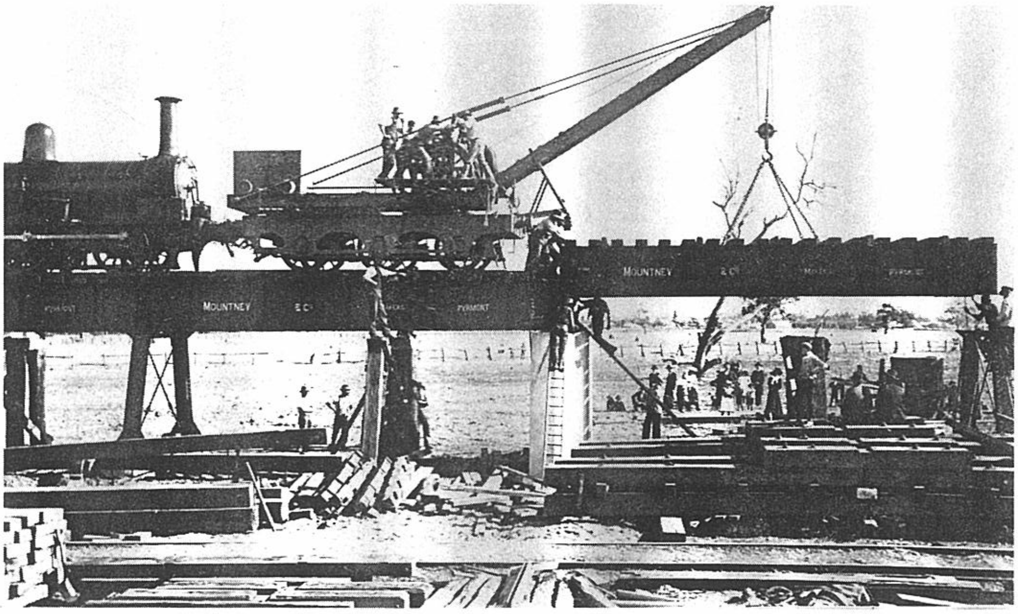
Piers immediately after removal of deck. Note concrete pier at every tenth pier.



Locomotive and crane with a 29'-6" span of steel girder running up ramp to main lines.



New girder and train approaching from South end of viaduct No.5.



New girder being lowered onto its new piers. Note hand-operated winch. Old wooden piers await removal.

Dubs D class loco with up Melbourne express crossing last of the timber girders onto a steel girder which has just been place.

that which was incurred during the reconstruction. No doubt the simplicity of the work and the large tonnage of metal work involved contributed to the low unit cost of the final structure. The quantities of steelwork involved were:

Steel girders	1350 tons
Steel trestles	350 tons
Miscellaneous metalwork	35 tons

The whole of the work was carried out by the Way and Works Brance of the NSWGR under the direct supervision of the Divisional Engineer, Goulburn, Mr W. Shellshear.

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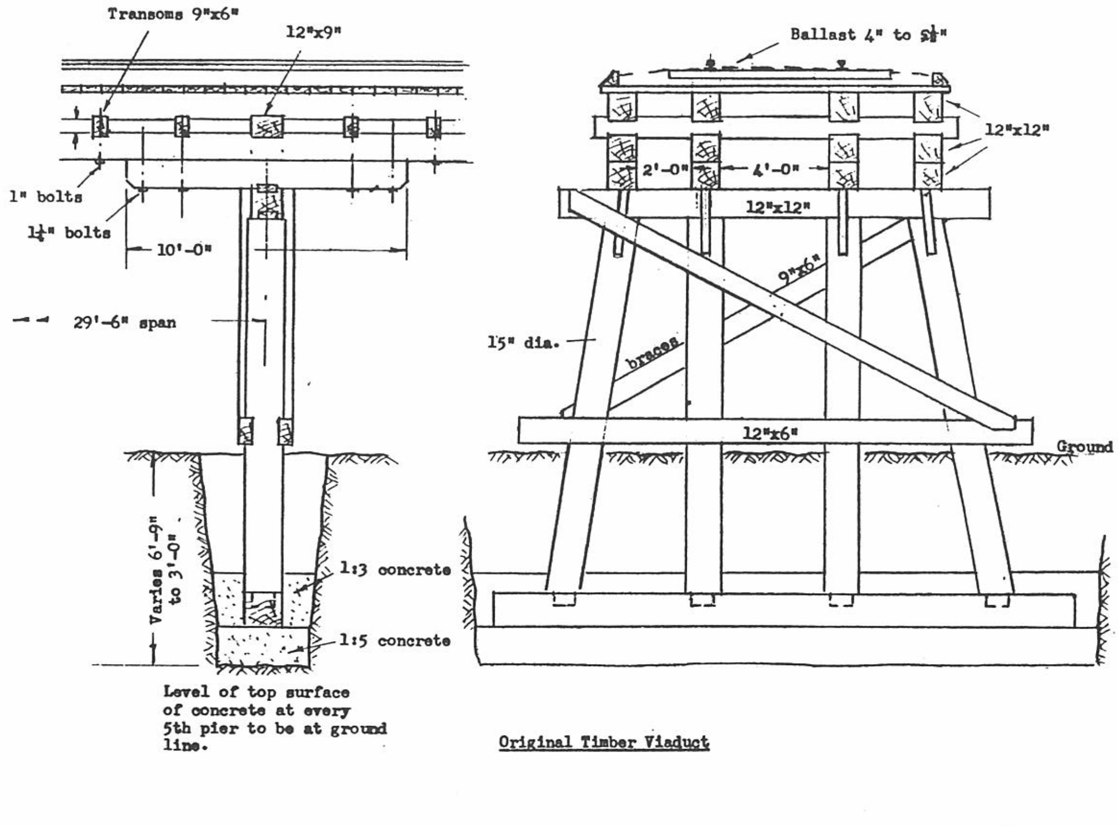
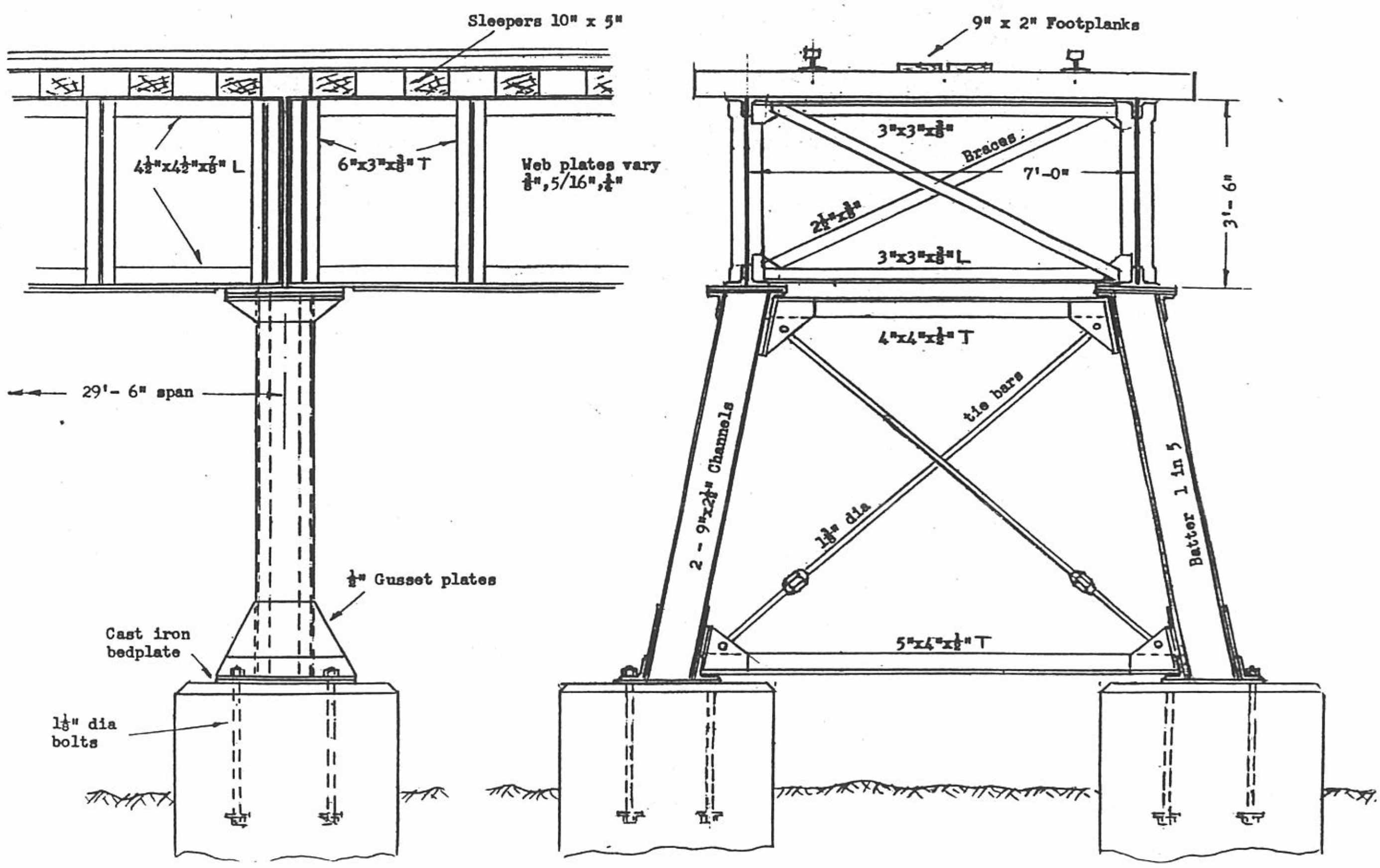
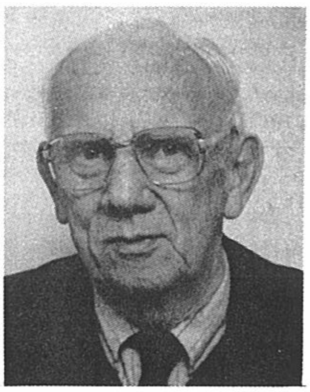
Photographs - The late W. Shellshear.



Original Timber Viaduct



Typical Details of Steel Girders and Piers



W.M. Shellshear holds the A.S.T.C. (Mech. Eng.) degree of the Sydney Technical College and gained his early engineering training as a Cadet Engineer with the N.S.W. Govt. Railways. Following this he was appointed an Asst. Design Engineer with the Sydney Metropolitan Water, Sewerage and Drainage Board. He served during the war in the Army Design Directorate as engineer responsible for design of infantry weapons and during this period graduated from the Military College of Science, U.K.

He joined the Snowy Mountains Authority at its inception in 1949 and had reached the position of Inspecting Engineer, Civil Works when he retired in 1973.

Since retirement he has held the positions of Hon. Secretary of the Division's Heritage Sub-committee. He is currently convenor of that sub-committee. He was part author of the Institution's publication "Canberra's Engineering Heritage" and is Honorary Life Member of the Australian Railway Historical Society.