NSW GOVERNMENT | Transport Roads & Maritime Services

GHD

Movable Span Bridge Study

Volume 1: Vertical Lift Span Bridges

I.Berger, D. Healy and M. Tilley

March 2015

Executive Summary

The Movable Span Bridge Study has been completed by GHD in conjunction with the Environment Branch of the Roads and Maritime Services (RMS). The study will play a vital role in assisting RMS in assessing and managing their heritage movable span bridges into the future.

RMS currently manages twenty six movable span bridges in NSW, of which fourteen are still operational. Between 1802 and 2005 there were five distinct types of movable bridge types built which included pontoon, lift, bascule, swing and sliding spans. In total 66 movable span bridges were constructed in NSW but many of these have now been demolished or are permanently closed.

This study documents the overarching history and individual past of the vertical lift span bridges, bascule bridges, and the sole remaining RMS swing bridge in NSW, along with the only table bridge in Australia. The study provides extensive research and background information utilising numerous documents and sources to establish each bridges history, engineering authenticity and enable their engineering heritage significance to be evaluated and assessed.

The detailed historical research into the development of movable span bridges in Europe and America has enabled a better appreciation of the influences that affected the design of the 48 vertical lift span and bascule bridges built in NSW between 1882 and 2005. Through comparative analysis of the lifting mechanisms of these bridges it has been possible to develop a classification system that identifies each of these bridges as belonging to one of 13 types; 8 for vertical lift span and 5 for bascule bridges. The first 6 vertical lift span types identified by this study can be properly recognised as Australian adaptations with no international equivalent.

This classification provides a better understanding of the performance and shortcomings of those movable span bridges that are still operational as these issues appear common to all bridges within a type. Another benefit of this classification is that it enables the standardisation of maintenance strategies across each type and the development of more consistent heritage and conservation management practices.

Lastly, we have provided and outlined maintenance, repair, rehabilitation and upgrade capacity strategies to ensure each movable span bridge types continued safe use into the future.

Cover Image: Barham Bridge Official Opening on 8 October 1904

Table of contents

Appendices

1. Introduction

GHD has been engaged by Roads and Maritime Services (RMS) to undertake a heritage assessment of the 26 movable span bridges in NSW with particular reference to their lifting mechanisms. The intention is to identify the separate components and their contribution to the heritage value of each bridge. This will be based on the uniqueness of the engineering and the condition of the fabric. The study will also include recommendations for repair or replacement of these lifting mechanism components in order to return or meet the current operational and safety requirements.

RMS advised that each of the 26 bridges has been subject to previous heritage assessments of differing levels of detail:

— 5 of the bridges are listed on the State Heritage Register (SHR) and have undergone highly detailed assessments.

— 21 of the bridges have entries on the RMS Section 170 register.

— 5 will require a separate new assessment. These include the Clarence River Bridge at Mororo (lift span), Batemans Bay Bridge (lift span), Wardell Bridge (lift span) the Swansea Bridge built 1989 (bascule) and the Bridge over the Darling River at Wentworth (lift table).

1.1 Scope and methodology

The following scope of work from RMS and associated work methodology was adopted to undertake the report:

— Search (or verify) all relevant statutory and non-statutory heritage databases and listings including:

  - Commonwealth Heritage List, National Trust heritage list (NT), Register of the National Estate (RNE), NSW State Heritage Register (SHR), NSW State Heritage Inventory (SHI), Section 170 Conservation and Heritage Registers (S170), Local Environment Plans (LEPs).

— Identify the location of 26 bridges on a single map.

— Review all available registered significance assessments of identified heritage items.

— Undertake primary and secondary research on the bridges and provide a succinct and well referenced historic summary of the bridges. Sources of documentation that were included but limited to:

  - RMS archives and library, historic photographs, NSW State Library, Heritage Branch library, community heritage information (eg: local studies library collection, local heritage associations, local historical society) and previous studies/research undertaken in the area, including grey literature.

— Undertake heritage assessments of all potential heritage items identified through research and site inspection.

- Establish the heritage significance (if any) of these items using the NSW Heritage Council seven criteria as outlined in the NSW Heritage Branch publication "*Assessing Heritage Significance*". Each criterion must be addressed (e.g) as having State, local or nil significance.
- Each bridge must also have a succinct *statement of significance* provided.
- Grade the different lift span components of the heritage item in terms of heritage significance, such as exceptional, high, moderate, nil and intrusive. To better explain this, provide a breakdown of these elements and the rationale in tabular and/or graphic form.

— Provide broad scale heritage constraints and opportunities, including professional and technical recommendations that would avoid, minimise or mitigate against impacts to the heritage values of the bridge. These recommendations should also outline relevant statutory approvals and/or notifications and best practise protocols in heritage management and further reporting requirements.

1.2 Heritage listings

The most relevant statutory listings for conducting future works on the bridges are the State Heritage Register, LEP and s170. The statutory listings for each bridge have been recorded within the inventory sheets as follows:

Table 1-1 Statutory and non-statutory listings

Heritage Listing	Status
Australian Heritage Database	Listed / not listed
OEH Heritage Division State Heritage Register	Listed / not listed
Local Environment Plan	Listed / not listed
NSW National Trust Register	Listed / not listed
RMS s170 Heritage and Conservation Register	Listed / not listed

1.2.1 State Heritage Register

The SHR is maintained by the OEH Heritage Division on behalf of the Heritage Council of NSW. The Register is a list of heritage items identified as being of State heritage significance. A listing on the SHR confers the highest level of legislative protection available for heritage items in NSW. As a listing on the SHR confers protection upon a heritage item, there are restrictions on what activities can be carried out on or adjacent to a listed item. These are covered under Section 57 of the NSW *Heritage Act* 1977. Section 57(1) of the Act states that:

When an interim heritage order or listing on the State Heritage Register applies to a place, building, work, relic, movable object, precinct or land, a person, must not do any of the following things except in pursuance of an approval granted by the approval body under Subdivision 1 of Division 3:

a. Demolish the building or work,

b. Damage or despoil the place, precinct or land, or any part of the place, precinct or land,

c. Move, damage or destroy the relic or movable object,

d. Excavate any land for the purpose of exposing or moving the relic,

e. Carry out any development in relation to the land on which the building, work or relic is situated, the land that comprises the place, or land within the precinct,

f. Alter the building, work, relic or movable object,

g. Display any notice or advertisement on the place, building, work, relic, movable object or land, or in the precinct,

h. Damage or destroy any tree or other vegetation on or remove any tree or other vegetation form the place, precinct or land.

Approval to conduct works upon an item listed on the SHR (other than routine maintenance) must be sought from the approval body, the Heritage Council of NSW. An application to conduct works upon or modify a SHR listed item can be made under Section 60 of the Act. The only exceptions to this are works covered in a CMP endorsed by the Heritage Council of NSW, or works for which a standard exemption has been granted by the Minister under Section 57(2) of the Act. The RMS is required to obtain a S60 permit from the Heritage Council in order to conduct the works outlined in this SOHI.

1.2.2 Section 170

Roads and Maritime Services Heritage and Conservation Register was established in accordance with Section 170 of the Heritage Act, 1977 to record all the heritage items in the ownership or under the control of Roads and Maritime Services.

The Heritage and Conservation Register has two main roles:

1. To meet Roads and Maritime Services' statutory requirements.
2. As an essential tool in total asset management, by listing and providing information on those Roads and Maritime Services assets which have heritage significance.

Information in the Register has been prepared according to OEH Heritage Division guidelines and corresponds with information in the State Heritage Inventory, maintained by the OEH Heritage Division.

1.2.3 LEP

Heritage schedules and controls of each relevant LEP have been searched.

1.3 Grading of heritage significance

To facilitate a better understanding of the manner in which each of the elements of a Bridge contributes to its overall significance, it is a useful management tool to separate a Bridge into its components and examine the heritage significance of each. This process allows for more informed analysis of what constitutes significant form and fabric, or what fabric is of little significance, or intrusive.

Table 1-2 Grading system used for heritage significance

Grading	Justification	Status
EXCEPTIONAL	Rare or outstanding element directly contributing to an item's local or State significance.	Fulfils criteria for local or State listing.
HIGH	High degree of original fabric. Demonstrates a key element of the item's significance. Alterations do not detract from significance.	Fulfils criteria for local or State listing.
MODERATE	Altered or modified elements. Elements with little heritage value, but which contribute to the overall significance of the item.	Fulfils criteria for local or State listing.
LOW	Alterations detract from significance. Difficult to interpret.	Does not fulfil criteria for local or State listing.
INTRUSIVE	Damaging to the item's heritage significance.	Does not fulfil criteria for local or State listing.

The table above provides a guide to the grading of significance of items or places of heritage value and is directly derived from the OEH Heritage Division *NSW Heritage Manual* (revised 2001).

1.4 Findings of the study

Whilst assessing the existing movable span bridges it was discovered that a significant number were informed by preceding designs. It was therefore considered paramount to thoroughly review all opening bridges in NSW to establish an accurate history of design evolution.

Consequently all known movable bridges constructed in NSW between 1882 through to 2005 have been researched as part of this study. The subset bridge types have been allocated a name following the convention of either the first recognised designer or bridge name and can be seen in Table 1-3 below.

Table 1-3 Movable span bridges by generation including subset types

No.	Study bridges	Informed the study	Built
I	**VERTICAL LIFT SPAN BRIDGES**		
I.i	**First Generation – Vertical Old**		
		Balranald TYPE	
		Balranald	1882
		North Bourke	1883
	Brewarrina TYPE		
1	Brewarrina		1888
		Mulwala TYPE	
		Mulwala	1893
		Wentworth	1893
		Tocumwal TYPE	
		Tocumwal	1895
		Wilcannia	1896
	Swan Hill TYPE		
2	Swan Hill		1896
3	Dunmore Bridge		1899
4	Tooleybuc Bridge		1925
5	Abbotsford		1928
	Hinton Bridge TYPE		
6	Hinton		1901
		Murwillumbah	1901
7	Cobram Bridge		1902
8	Barham Bridge		1905
I.ii	**Second Generation – Vertical New**		
	Robinvale TYPE		
		Robinvale	1925
9	Gonn Crossing		1926
10	Mororo		1935
		Boyds Bay	1937
		Martin	1940
11	Nyah		1941
	Ryde TYPE		
12	Ryde		1935
13	Hexham		1952
14	Batemans Bay		1956
15	Wardell		1964
16	Harwood		1966
I.iii	**Table Lift**		
17	Wentworth		1969

No.	Study bridges	Informed the study	Built
II	**BASCULE SPAN BRIDGES**		
II.i	**First Generation**		
	Drawbridge TYPE		
		Belmore	1891
		Camden Haven	1891
		Sheas Creek	1892
		Kinchela Creek	1893
II.ii	**Second Generation**		
	Bélidor TYPE		
		Telegraph Point (timber)	1902
		Swansea (first - timber)	1909
18	Glebe		1905
		Darling Point	1905
19	McFarlane		1906
		Kyalite	1912
20	Carrathool		1922
		Sheas Creek Rail	1925
II.iii	**Third Generation – Modern Bascules**		
	Strauss TYPE		
		Spit (first)	1924
		Menindee	1927
21	Narooma		1931
		Lansdowne	1934
		Barney Point	1936
	Rolling Lift - Rall TYPE		
22	Grafton		1932
	Simple Trunnion TYPE		
23	Swansea (north bound)		1955
24	Spit		1958
25	Swansea (south bound)		1989
		Broadwater (Council owned)	2005
III	**SWING SPAN BRIDGES**		
		Wentworth Park	1850
		Pyrmont	1857
		Glebe Island	1862
		Hay	1873
		Gladesville	1884
		Fig Tree	1885
	Pyrmont TYPE		
	Pyrmont		1902
26	Glebe Island		1903

2. Summary history of movable span bridges

Movable bridges are one of the oldest types of bridges known to humankind. The bascule or draw span was developed by Europeans during the Middle Ages. There was a resurgence of movable bridges during the late 19th century. Reliable electric motors and techniques for counterbalancing the massive weights of the bascule, lift or swing spans marked the beginning of modern movable-bridge construction. They are usually found in flat terrain, where the cost of approaches to gain high-level crossings is prohibitive, and their characteristics include rapidity of operation, the ability to vary the openings depending on the size of vessels, and the facility to build in congested areas adjacent to other bridges.

2.1 Ancient movable bridges

The earliest known example of a draw bridge appears in Egyptian monuments from 1355 BC, on which Rameses II celebrated his victories over fortified cities. Wall paintings within temples and palaces of this period depict bridges as crossing the moats around castles and fortified towns. It has been observed that the Egyptians built no permanent bridges across the Nile, but were familiar with framing trestle work, and with pontoon draw bridges (Knight, 1876).

In around 460 B.C, Queen Nitocris of Babylon built a bridge across the Euphrates, after temporarily diverting the water. The Histories of Herodotus record that the piers were of stone blocks bound together with iron and lead, and the spans were wooden platforms built so that they could be withdrawn at night, to prevent people passing from side to side of the river (Knight, ibid).

Otis Ellis Hovey in his work Movable Bridges (1926) describes in considerable detail other later movable bridges built in Imperial China and within the Roman Empire; the interested reader is directed to this excellent source book on the subject.

2.2 History of movable bridges in New South Wales

Until the gold rushes of the 1850s, settlement in New South Wales was confirmed mainly to the narrow coastal strip. It comprised less than one-tenth the area of the Colony but included all the major settlements such as Sydney and Newcastle. Most of the coastal rivers were navigable and so the population, more than 80% of the Colony, were well-served by ships plying the east coast of Australia. For the direct crossing of these rivers, a variety of small boats was used, however, by the 1840s the now-familiar punt/ferry was in use.

The adequacy of the coastal shipping trade and the cost of building high-level bridges across the wide tidal reaches meant the few road bridges were constructed across navigable waterway. Therefore, the twenty-six coastal bridges that were built prior to 1915, Table I, were all low level bridges with opening spans, and punts or ferries. These remained the principal means of crossing the navigable sections of the coastal rivers well into the twentieth century. However, above the navigation limits, there were easier crossing sites such as fords, and, sites where relatively cheap timber bridges could be built, but it usually involved a lengthy detour to use them.

During the period under review, the cost of transporting goods within the coastal belt was generally low, despite ferry tolls, and goods moved with reasonable speed, due mainly to the efficiency of the coastal shipping trade. The short road haul between rivers was not a significant problem. For most of the colonial period conditions were the reverse west of the Dividing Range.

Prior to 1850, the western region of New South Wales was thinly settled by squatters who managed huge sheep runs. Transport cost, for the long haul overland to Sydney, were very high, but the world demand for fine Australian wool was even higher, so wool survived as the only profitable commodity.

During and after the gold rushes, and following the Crown Lands Alienation Act of 1861, more people settled in the west and south-west of the Colony, particularly the Riverina District. Settlers also streamed north from Victoria and eastwards from Adelaide into the productive farming and wool country bordering the Murray and Murrumbidgee Rivers.

As with the upper reaches of the coastal rivers, crossing the inland rivers began at fords and with punts. The latter were usually timber pontoons, 40 feet long, 15 feet wide and 3 feet 7 inches deep (12 m x 4.5 m x 1.1 m) with a clear deck of 11 feet (3.3 m) between the kerbs. They were hand-operated through a wire cable across the river and a set of gears on the punt, and cost around £350 (Dare, 1911). By the turn of the century there were approximately 85 of these punts throughout New South Wales (Public Works Department Annual Reports).

Although better than fording a river, using punts had its problems. Capacities were inadequate and their operation was slow and unreliable, consequently, considerable delays and congestion occurred at most sites. Also, the ferry was usually leased and the owner/operator had a monopoly of the service, which led to many disputes about excessive charges. Farmers often paid dearly for the use of punts and ferries. But that was not all, there was a social problem, due to the shanties and taverns at or near the crossings. Hard-earned wages of the teamsters were wasted on drink and there were frequent reports of brawling and other anti-social behavior. The Governments were also concerned about the unsocial behaviour that occurred at taverns located near crossings and constructing toll free bridges would solve all the above concerns (Fraser, 1985).

Toll-free bridges were the answer but permanent bridges such as those built at Albury in 1861 and at Wagga Wagga in 1862, could cost between five and ten times the cost of a punt, so it required special circumstances to justify the construction of the fifteen expensive movable span bridges across the inland rivers. These circumstances were the development of the river trade and the arrival of the railways to the banks of those rivers.

The era of the river trade began in 1853 when the paddle-steamer “Mary Ann” travelled the Murray River from Mannum (near Murray Bridge, South Australia) to Goolwa (at the mouth of the Murray) and returned with store for sale to settlers along the way (Fraser 1983). The transport system that developed and which enjoyed boom conditions over the next twenty-five years, favoured South Australia and Victoria at the expense of the New South Wales. The rural wealth of western and south-western New South Wales flowed with the Murray, Murrumbidgee and Darling Rivers to those rival colonies.

Capturing the river trade, and redirecting it to Sydney, virtually became an obsession with successive Governments of New South Wales. The method of achieving this in the 1880s was to build railway extensions to the inland rivers and use the existing opening span bridges, and some new ones, in order to give access across the rivers to the railheads. What the ships were to the Coast, the railways became to the Western Slopes and Plains.

At most of the sites where bridges have been erected over these inland rivers the banks are low, so that a fixed bridge with sufficient headway, even with a graded approach spans, would have been of such a length as to be too costly for the service to be provided, even if heavy team traffic did not render graded approach spans inadvisable (Allan 1924).

The railways revolutionised land transport in New South Wales. The overall effect is beyond the scope of this paper except to note that the desired result was achieved. There was a rapid decline in the river trade such that by 1915 most of the movable span bridges no longer served their original function, and the coastal shipping trade suffered the same fate once the North Coast Railway was built 1915-1923. Consequently, most of the opening span bridges of the colonial period have been replaced (Fraser, 1985).

In summary, the majority of bridges were preceded by punts, which although better than having to ford a river, still had problems in terms of their low capacity, slow operation, and the monopoly held by most operators, which led to many disputes over excessive charges. On the majority of crossings, a simple bridge was the answer, but on the navigable stretches of rivers such as the Paterson, Murrumbidgee, Darling and Clarence, provision had to be made to allow free passage of river traffic. Opening span bridges were the answer. Five types of opening span bridges were built in NSW prior to 1915, these being:

1. **Pontoon or floating bridges** – a series of pontoons or barges moored end to end with allowance for one or two units to be floated clear to allow passage of river traffic.
2. **Sliding, traversing, draw or retractable bridges** – the opening span as a counter-balance portion, projecting over the fixed part of the bridge, with the whole unit sliding horizontally on a system of rails and rollers
3. **Swing or pivoting bridges** – these bridges rotate or pivot horizontally about a vertical axis. Symmetrical swing bridges provide an opening on each side of the central pivot, which balances the structure. In cases where a single-opening span is used, some form of short counterbalance is built on the other side.
4. **Bascule bridges** – also known as draw bridges. The moving span is hinged at one end and swinging from the horizontal into a near-vertical position.
5. **Lift bridges** – the movable portion remains horizontal and is lifted vertically. The amount of headroom available is determined by the variations between water levels and the heights of the lift towers. Water

traffic beneath these bridges is restricted to low-masted craft, barges and tugs (Fraser, 1985:71-4).

Table 2-1 List of all movable span bridges built in NSW

	Bridge Name	Description	Opening span length	Construction date	Status
1	Windsor, South Creek	Pontoon		1802	Replaced 1813
2	Blackwattle Creek Bridge, Wentworth Park	Swing		1850	Replaced prior to 1896
3	Pyrmont Bridge (first), Darling Harbour, Sydney Pyrmont Bridge, Darling Harbour, Sydney	Lattice Swing Sliding	15.7 m & 10.8 m 9.0 m	1857 1862	Replaced 1902 Replaced 1902
4	Hopwood's Pontoon Bridge at Echuca, Murray River	Pontoon		1858	Replaced 1878
5	Glebe Island Bridge (first) over Johnstons Bay, Sydney	Plate Swing	10.4 m	1862	Replaced 1901
6	Dunmore Bridge, Paterson River	Sliding	13.7 m	1864	Replaced 1899
7	Swansea Bridge, Lake Macquarie	Sliding	14.3 m	1871	Replaced 1909
8	Brewarrina, Barwon River	Pontoon		1872	Replaced 1888
9	Hay Bridge, Murrumbidgee River	Lattice Swing	Two 15.1 m	1873	Replaced 1973
10	Gladesville Bridge over Parramatta River, Lane Cove near Sydney	Lattice Swing	Two 16.5 m	1881	Replaced 1964
11	Balranald Bridge, Murrumbidgee River	Lift	15.0 m	1882	Replaced 1973
12	North Bourke Bridge, Darling River	Lift	15.1 m	1883	Permanently closed
13	Wilsons Creek Bridge at Lismore	Sliding	15.1 m	1884	Replaced
14	Lansdowne River Bridge at Coopernook (first)	Sliding	15.2 m	1884	Replaced 1934
15	Punt Bridge over Erina Creek at East Gosford	Sliding	13.7 m	1885	Replaced 1963
16	Figtree Bridge over Lane Cove River	Swing	14.3 m	1885	Replaced
17	Cooks River Bridge at Botany Sewage Farm	Sliding	8.5 m	1887	Replaced 1916
18	*Brewarrina Bridge, Barwon River (BN 4854)	Lift	14.6 m	1888	Permanently closed
19	Gladstone Bridge, Belmore River	Bascule	12.2 m	1891	Replaced 1984
20	Camden Haven River Bridge	Bascule	12.2 m	1891	Replaced

	Bridge Name	Description	Opening span length	Construction date	Status
21	Shea's Creek Bridge, Canal Road, St. Peters/ Mascot	Bascule	12.2 m	1892	Replaced 1937
22	Kinchela Bridge, Kinchela Creek	Bascule	12.2 m	1893	Replaced 1925
23	Mulwala Bridge, Murray River	Lift with four McDonald truss spans	14.1 m	1893	Replaced 1924
24	Wentworth Bridge, Darling River	Lift with three McDonald truss spans	14.1 m	1893	Replaced 1969
25	Tocumwal Bridge, Murray River	Lattice Lift	15.4 m	1895	Replaced 1989
26	Wilcannia Bridge, Darling River	Lift with two lattice truss spans	15.4 m	1896	Permanently closed. Pedestrian use only
27	*Swan Hill Bridge, Murray River (BN 3215)	Lift with two Allan truss spans	18.4 m	1896	Operational
28	*Dunmore Bridge, Paterson River (BN 1683)	Lift with three Allan truss spans	16.7 m	1899	Permanently closed
29	*Glebe Island Bridge over Johnstons Bay, Sydney (BN 61)	Swing Bridge MR165	29.2 m	1901	Operational
30	*Hinton Bridge, Paterson River (BN 1482)	Lift with two Allan truss spans	16.7 m	1901	Permanently closed
31	Murwillumbah Bridge, Tweed River	Lift with four Allan truss spans	16.7 m	1901	Replaced 1968
32	*Cobram Bridge, Murray River at Barooga (BN 3247)	Lift with two De Burgh truss spans	15.0 m	1902	Currently locked, adjacent bridge restricts lift clearance
33	Telegraph Point Bridge over Wilson River, near Port Macquarie	Bascule, curved path counterweight	12.2 m	1902	Replaced 1974

	Bridge Name	Description	Opening span length	Construction date	Status
34	Pyrmont Bridge over Cockle Bay, Darling Harbour, Sydney	Swing Bridge	34.0 m	1902	Operational. Pedestrian use only
35	*Glebe Bridge, Richmond River at Coraki (BN 2462)	Bascule, curved path counterweight	18.6 m	1905	Currently locked but still operable
36	*Barham -Koondrook Bridge, Murray River (BN 3256)	Lift with two De Burgh truss spans	17.7 m	1905	Currently locked but still operable
37	Darlington Point Bridge, Murrumbidgee River	Bascule, curved path counterweight with a single De Burgh timber truss	18.6 m	1905	Replaced 1975
38	*McFarlane Bridge, Clarence River at Maclean (BN 2537)	Bascule, curved path counterweight	18.6 m	1906	Currently locked but still operable
39	*Swansea Bridge, Lake Macquarie	Bascule (timber tower), curved path counterweight	18.6 m	1909	Replaced 1955
40	Kyalite Bridge, Wakool River	Bascule, curved path counterweight with a single Dare truss	18.6 m	1912	Replaced 1981
41	*Carrathool Bridge, Murrumbidgee River (BN 3248)	Bascule, curved path counterweight with two Allan truss spans	20.2 m	1924	Currently locked but still operable
42	Spit Bridge over Middle Harbour, south of Seaforth	Double-leaf Bascule	18.9 m	1924	Replaced 1958

	Bridge Name	Description	Opening span length	Construction date	Status
43	*Murray River, Tooleybuc (BN 3244)	Lift with two Allan truss spans	17.8 m	1925	Currently locked but still operable
44	Murray River at Robinvale, Mildura (BN 51870	Lift with four steel Pratt truss spans	16.7 m	1925	Replaced 2006
45	*Murray River at Gonn Crossing (BN 3375)	Lift	18.8 m	1926	Operational
46	Darling River, Menindee	"Strauss" Bascule.	14.5 m	1927	Counterweight and towers removed in 1970. Remains in use as a rail bridge
47	*Abbotsford Bridge, Murray River at Curlwaa (BN 5149)	Lift with four steel Pratt truss spans	19.8 m	1928	Operational (manual)
48	*Narooma, Wagonga Inlet (BN 5972)	"Strauss" Bascule with two steel Pratt truss spans	19.2 m	1931	Operational
49	*Clarence River Bridge at South Grafton (BN 2322)	"Rall" Bascule with six steel Pratt truss spans. Also carries rail.	25.6 m	1932	Permanently closed
50	Lansdowne River, Coopernook (BN 1805)	"Strauss" Bascule	19.0 m	1934	Replaced 1999
51	*Clarence River, Mororo (BN 2154)	Lift with two steel Pratt truss spans	17.7 m	1935	Permanently closed
52	*Uhr's Point aka Ryde Bridge, Parramatta River (BN 437)	Lift with two steel Pratt truss spans	34.7 m	1935	Permanently closed
53	Barneys Point Bridge, Tweed River	"Strauss" Bascule with two steel Pratt truss spans	15.1 m	1936	Replaced 1999

	Bridge Name	Description	Opening span length	Constructio n date	Status
54	Boyds Bay Bridge over Terranora Creek, Tweed Heads	Lift.	13.7 m	1937	Replaced 1985
55	Martin Bridge over Manning River, Taree	Lift with ten steel Pratt truss spans	18.2 m	1940	Permanently closed
56	*Murray River at Nyah (BN 3377)	Lift	18.6 m	1941	Operational
57	*Hexham, Hunter Bridge (BN 1378)	Lift	37.9 m	1952	Operational
58	*Swansea Bridge, Lake Macquarie (BN 1365)	Double-leaf Bascule	27.1 m	1955	Operational. Duplicated 1989
59	*Clyde River, Batemans Bay (BN 5950)	Lift with six steel Pratt truss spans	28.7 m	1956	Operational
60	*Spit Bridge over Middle Harbour, south of Seaforth (BN 50)	Bascule	39.92 m	1958	Operational
61	*Wardell Bridge, Richmond River, south of Ballina (BN 2166)	Lift	25.4 m	1964	Operational
62	*Clarence River, Harwood (BN 2151)	Lift with four steel Pratt truss spans	37.8 m	1966	Operational
63	*Darling River, Wentworth (BN 5130)	Table	20.7 m	1969	Operational
64	*Swansea Bridge, Lake Macquarie (BN 7828)	Double-leaf Bascule	26.2 m	1989	Operational
65	Broadwater Bridge, Richmond River	Bascule from Barneys Point Bridge reused in conjunctio n with a modern concrete bridge	15.1 m	2005	Operational

*Bridges included in RMS Environmental Branch study. Information sourced primarily from Dare (1896) and Fraser (1985).

2.3 Geographical spread

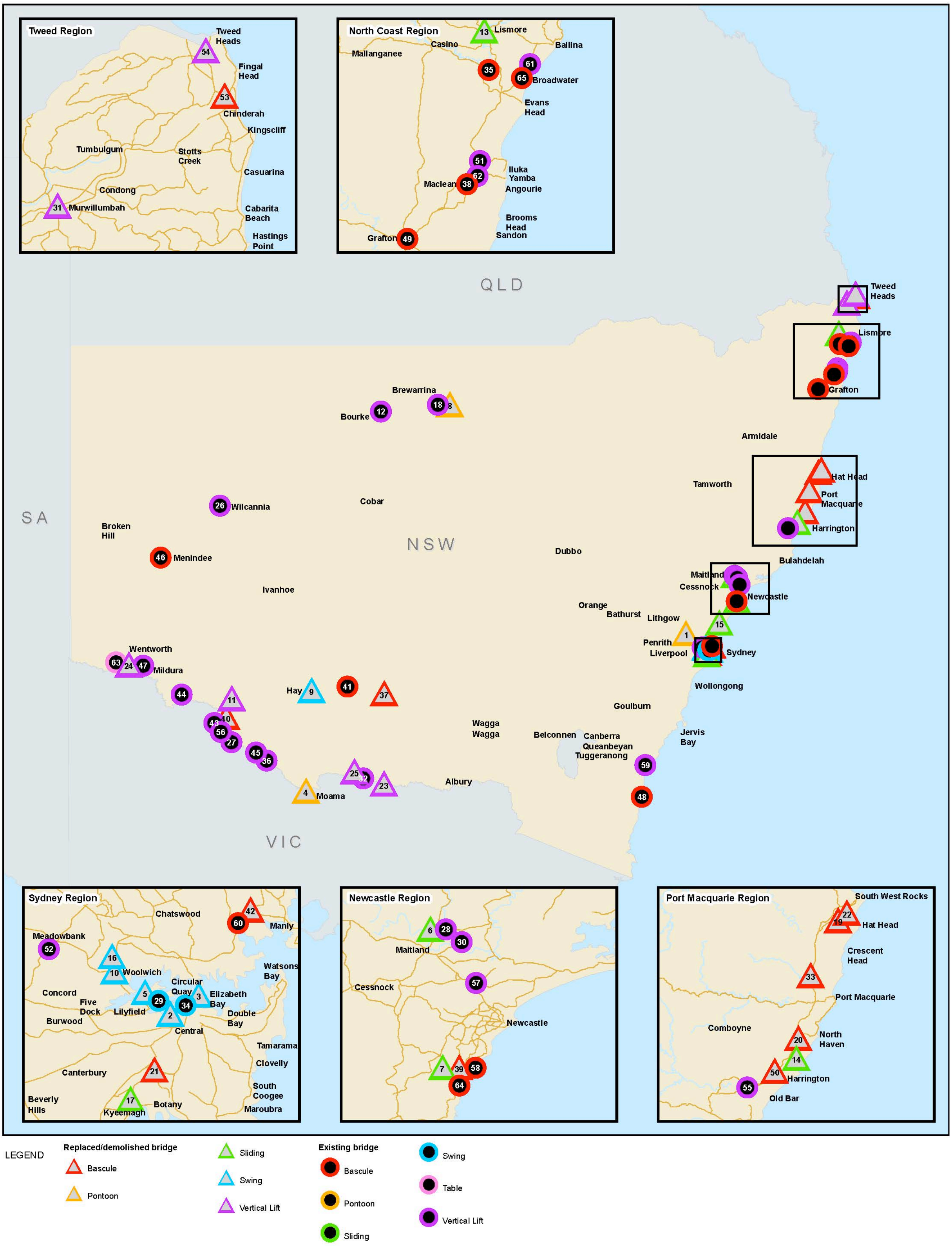

Figure 2.1 Movable span bridges built in NSW

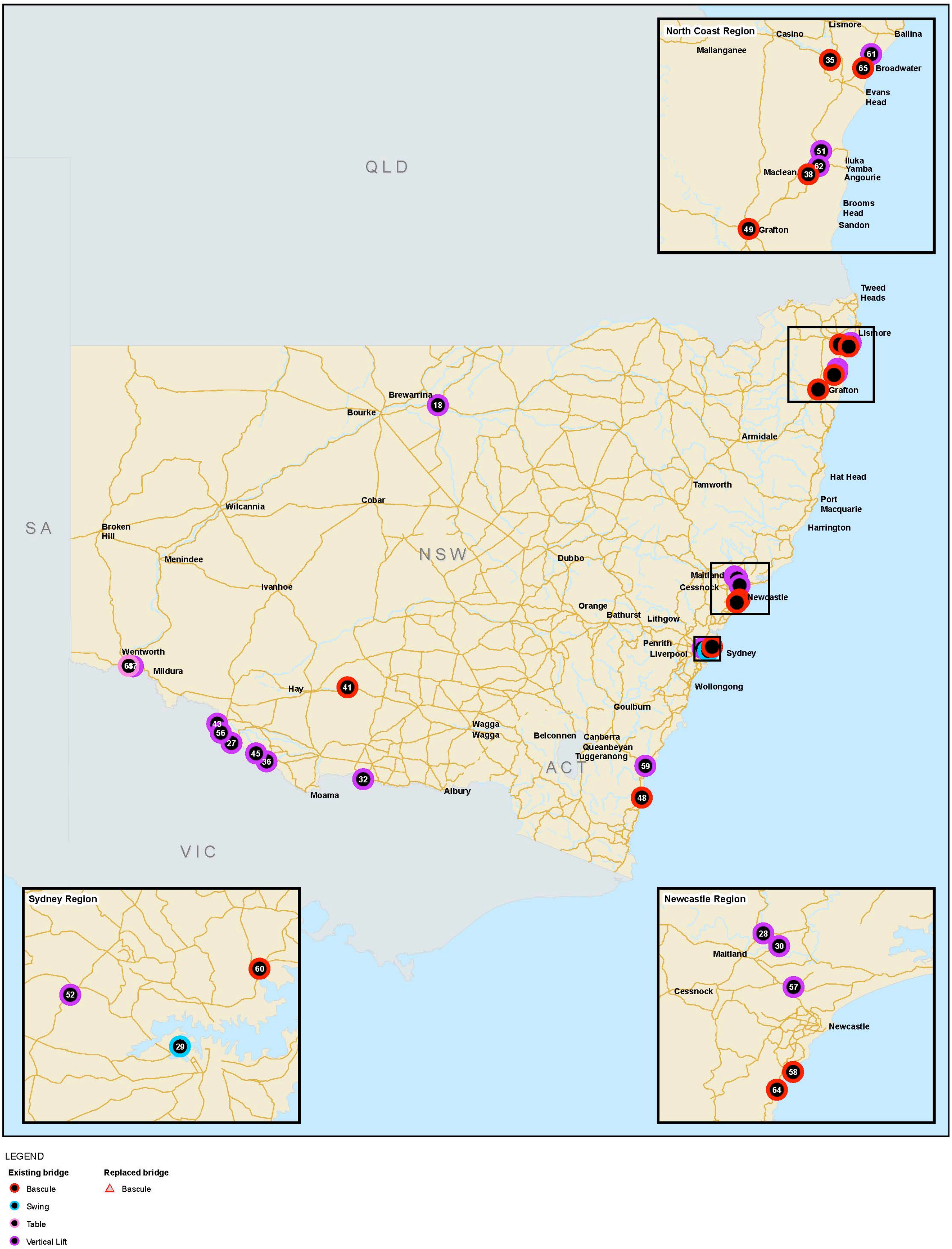

Figure 2.2 Movable span bridges built in NSW included in report

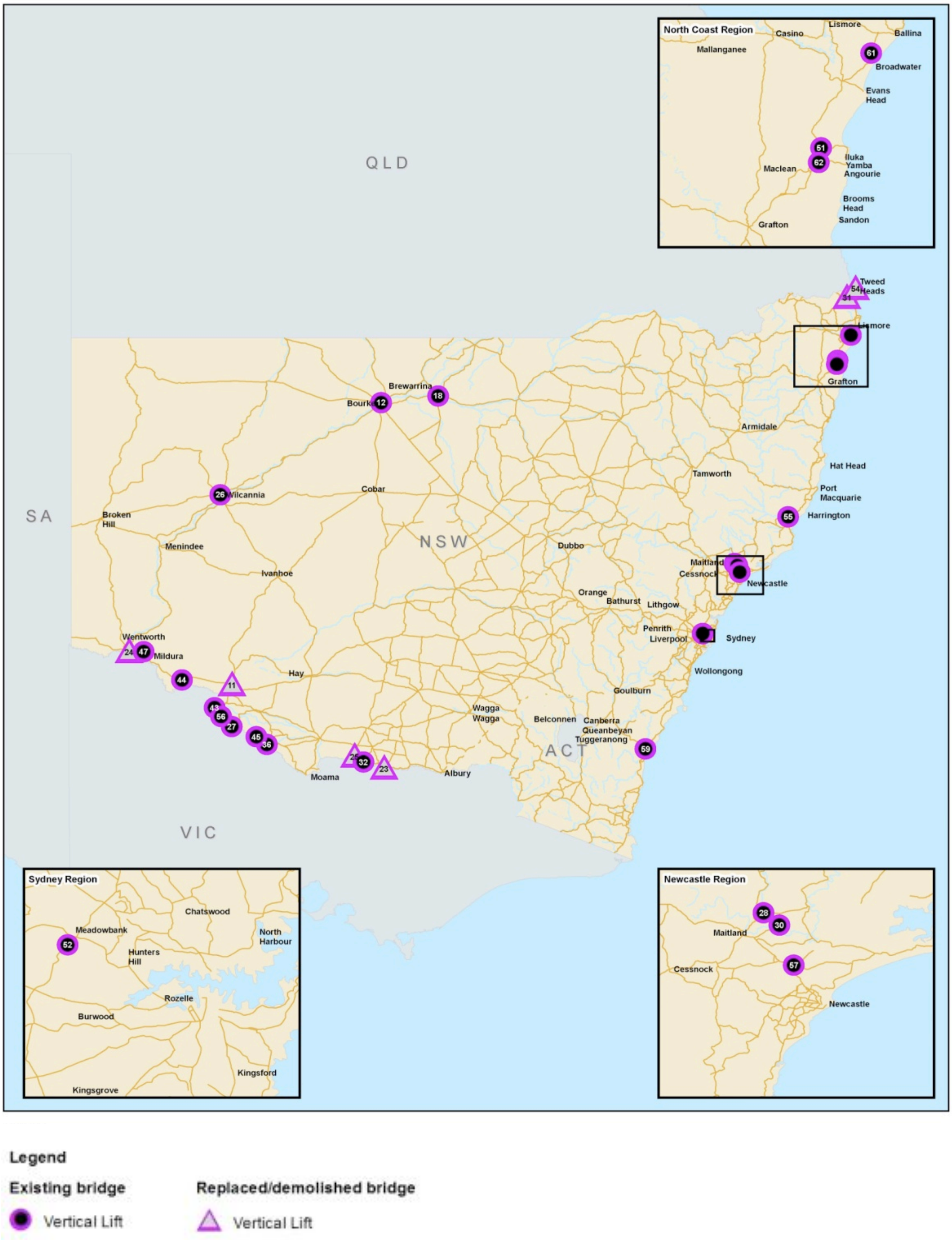

Figure 2.3 Vertical lift span bridges built in NSW

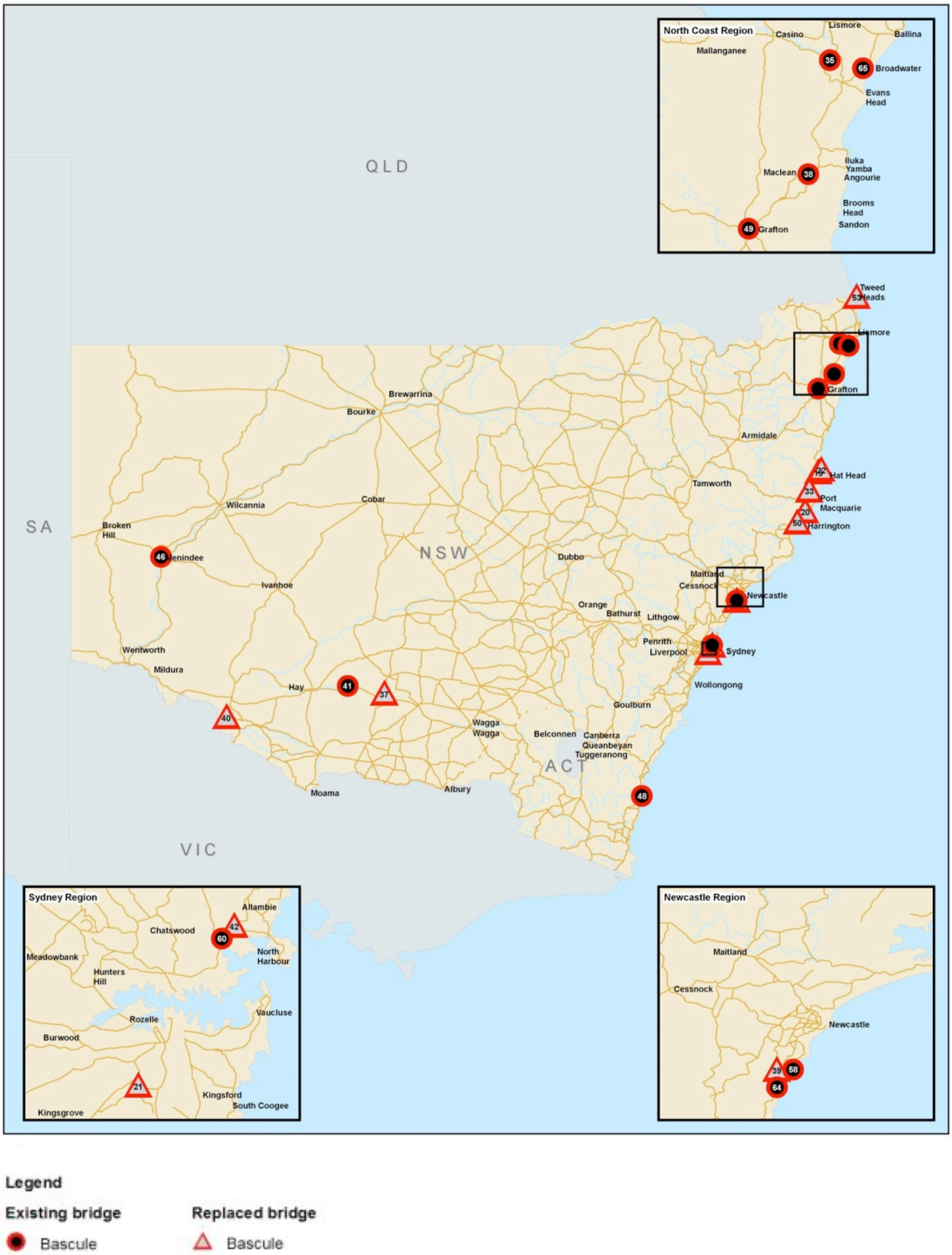

Figure 2.4 Bascule span bridges built in NSW

3. Developing and inland water network in NSW

3.1 Coastal shipping

Rugged country and larger rivers surrounding Sydney precluded early exploration inland, so it was only natural that the waterways be used for transport and access. With the development of coastal settlements at Newcastle, Wollongong, Eden and Grafton the earliest form of mass transport used was shipping.

From 1831, with the arrival of the first steamship (the *Sophia*) from England, maritime transport was set to enter a new and important era (Ross 1993). Numerous private steamship companies were formed up and down the NSW coast to provide regular coastal services (Figure 3.1). An example of this was the manner in which Ben Boyd's vessels serviced his community at Boydtown, near eden delivering supplies and transporting livestock and wool out of the area. For many years this remained the fastest and most reliable form of transport between the southern Monaro and Sydney. To some extent, road transport links were delayed to many of these communities, such as Eden, Grafton, Lismore and Ballina, because of such reliable and efficient maritime service.

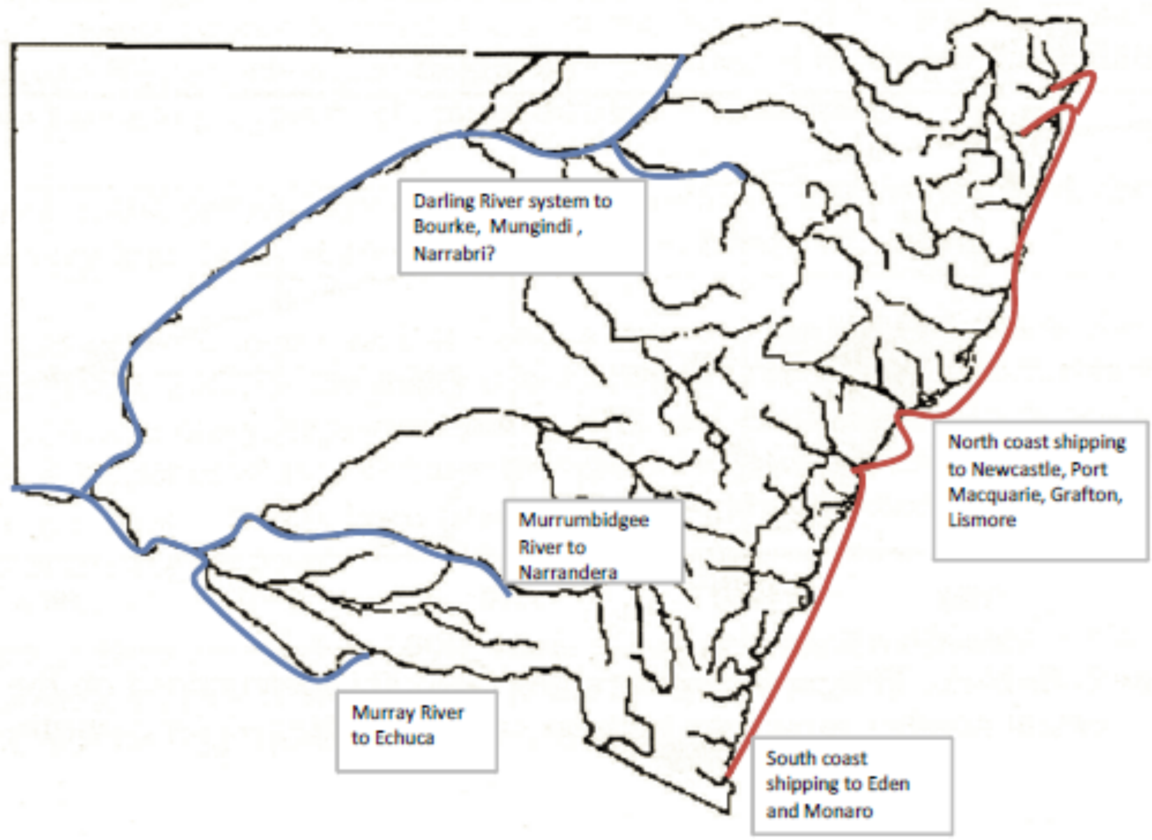

Figure 3.1 Principal water transport routes in NSW by 1894 (Source: Fraser, 1985)

The next section will focus separately on the Inland Rivers (Murray, Darling and Murrumbidgee) and the Northern Rivers (Clarence and Richmond).

3.2 The Murray, Darling and Murrumbidgee

3.2.1 Introduction

For several decades late in the nineteenth century, between about 1860 and 1890, the rivers of the Murray-Darling were important trade routes carrying wool for export from thriving pastoral properties and returning with supplies for these station. River traders became partners in the booming wool industry and prospered. But river trade did not become a permanent feature of the Australian scene because other, newer, transport methods provided better, and more economically attractive, ways of handling freight.

During the decades of successful river trade two major factors underlay activities. One was the political reality that the navigable parts of the Murray-Darling system flowed through three bitterly competitive, independent colonies (New South Wales, Victoria and South Australia). The environmental reality was that river flow in the Murray-Darling, especially on the Darling River, was intensely seasonal. During a normal year, water levels varied from so high that rivers broke their banks and it was hard to identify the river's course; at other times of the year there was so little water that rivers became collections of waterholes.

The river trade had its genesis in the spread of the pastoral industry across south-east Australia inland from Sydney. Initial expansion was from Sydney towards Port Phillip then pastoralist-explorers moved down the Murray establishing pastoral properties. In 1848 Murray Downs Station of 600 square kilometres was taken up opposite present-day Swan Hill. Initial stocking of the property which became Mildura took place in 1846; this was then very deep in the unknown wilderness. Wool produced on these properties had to be carried by bullock dray to the nearest coastal port or railhead for export, usually to England. But roads and track were non-existent or barely formed and progress of the bullock drays was subject to weather; transport was slow and expensive and an alternative would be welcome (Younger 1976).

The River Murray had been widely viewed as a potential transport route into the interior when the colony of South Australia was established. When Charles Sturt voyaged down the Murray in 1829-30 he wrote that the river was navigable by vessels much larger than his whaleboat, he also considered the Darling River navigable, but nothing was done to make that vision a reality until 1850 when South Australia's Governor "offered a bonus of £2,000 for the first two iron steamers of over 40hp, and with a draught no more than two feet to travel up the Murray from Goolwa to the Darling Junction" (Mudie 1961:15). A jetty had been built at Goolwa and beacons and navigational markers had been erected between Goolwa and Wellington across Lake Alexandrina to encourage private enterprise to begin river trading. Still nothing happened until the discovery of gold in Victoria, and the opportunity of delivering stores to the diggings via the Murray River and tributaries if the route could be pioneered.

3.2.2 The beginning

In 1853 two paddle-steamers competed for the bonus on offer. The small *Mary Ann* had begun carrying local cargo around the Murray mouth area in March 1853; the *Lady Augusta* had been completed in Sydney in mid-1853 and sailed around to Encounter Bay then across the Murray bar. In August 1853 the water level in the Murray was high enough and both boats set off upriver, *Mary Ann* captained by William Randell reached Moama and *Lady Augusta*, captained by Francis Cadell and towing the barge *Eureka*, reached Swan Hill, both well beyond the Darling River junction. Neither vessel met the full conditions for the Governor's award but both were rewarded for their success. More importantly, *Lady Augusta* bought more than five tonnes of wool on *Eureka* back to Goolwa. The voyage from Goolwa to the Darling River Junction took the *Lady Augusta* less than a fortnight. Previous drays took nine weeks for the trip from Adelaide – land transport was expensive and time-consuming. River traffic offered a quicker, more competitive and viable alternative to isolated western properties. River boats also offered comfortable travel for passengers. Thus "the great change the steamers were to bring about in the river country had begun" (Mudie 1961:42).

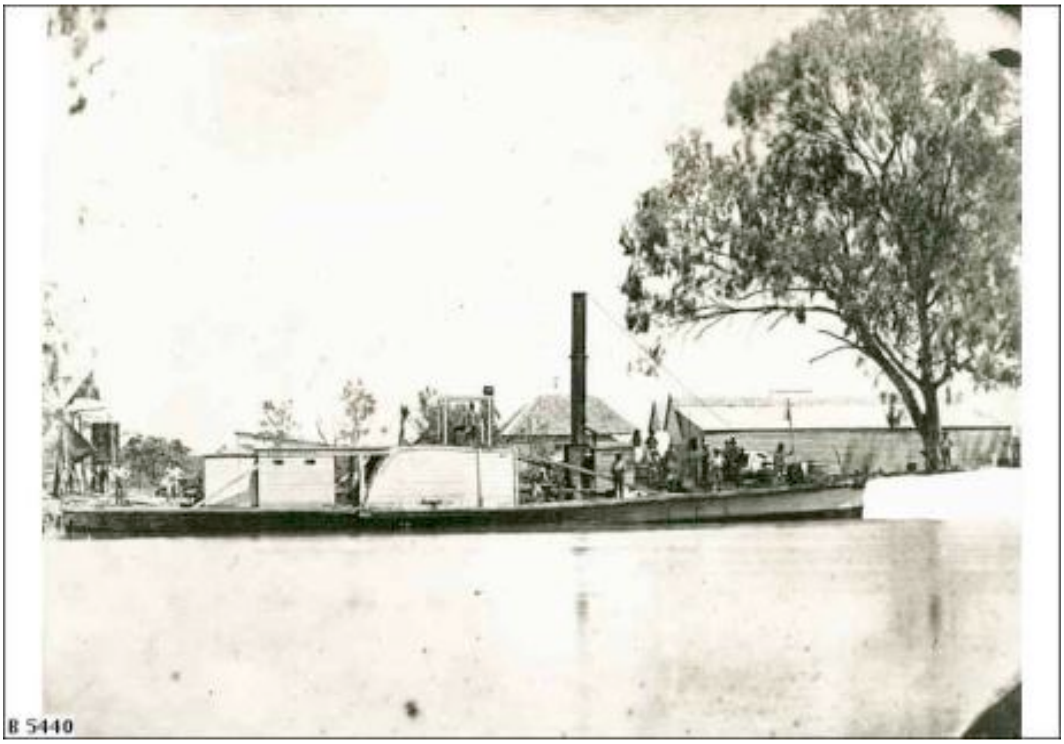

Figure 3.2 The "Lady Augusta", at Mannum in 1864 (Source: Library of South Australia)

The captains of both vessels set up commercial riverboat operations and other operators begun running paddle-steamers. By 1855 there were five paddle-steamers on the river and Randell was building more in his Mannum shipyard. River boats offered a far cheaper means of getting wool to the coast than bullock wagons and station owners were willing customers. Availability of riverboats, and the lower freight costs they offered, resulted in more sheep stations being established along the rivers.

This was a mutually beneficial process, more sheep stations produced more wool and encouraged more paddle-steamers to enter the trade; more paddle-steamers encouraged potential settlers to take-up more sheep stations because they could reliably send their wool to market. South Australia had led the way but by the mid-1860s shipping companies were being established along the rivers in New South Wales and Victoria. The river trade had begun an expansion that would take it to between 200 and 300 boats operating on the Murray River system at its peak.

As further assistance to the river trade, the South Australian government built the *Grappler* in 1858. She was designed and built specifically to remove snags from the river and carried a crane able to lift 14 to 15 tonnes, or logs one and a half metres in diameter. Snags are the remains of trees in the river, trees that have either been flushed downstream during floods and become stranded, or trees that have toppled into the river from the adjacent bank. With their branches and roots largely underwater they created an enormous hazard to shipping and their removal was beneficial to the trade. An alternative to removing snags was to whitewash the most dangerous parts to make them more visible, or to cut them off at the summer (i.e. low) river level (Younger 1976).

3.2.3 Mouth of the Murray

The original river trading intention was for riverboats to continue out of the Murray and take their cargo to Port Adelaide but the Mouth of the Murray proved unsafe for navigation. A few riverboats were reported to have safely crossed the bar at the mouth of the Murray on a number of occasions but the general opinion was that the river mouth was not safe, nor could it be made safe, for routine shipping movements. Enough vessels were lost trying to cross the bar to support that belief.

Goolwa, located on the last bend before the river reached the sea, was selected as the place where riverboats would unload cargo from inland for transfer to ocean-going ships. Port Elliot was selected as the ocean port and a railway was built between Goolwa and Port Elliot. The railway, operated by draught horses pulling the carriages, was completed in 1854; this was the first railway in Australia. There had been some talk of digging a canal between Goolwa and Port Elliot but nothing came of that idea because of difficulties at Port Elliot (Buxton 1967).

Port Elliot was not a success. The water was shallow and the jetty was not long enough for the railway to reach anchored ships so wool bales had to be loaded by boat and barge. As well, offshore rocks made navigation difficult and the bay was not sheltered; it was frequently battered by gales from the Southern Ocean. In 1864, after seven ships had been sunk at Port Elliot, port activity was moved along the coast to Victor Harbor. The horse-drawn railway from Goolwa was extended to Victor Harbor which became the main access point for goods travelling up and down the Murray River.

3.2.4 The River trade

During the later 1850s and early 1860s the practical limits of navigation on the rivers was found by trial and error. Along the Murray, Albury had been reached in 1855 and the Murray was understood to be usually navigable, at least for shallow draught vessels, from Goolwa as far upstream as Echuca.

The Murrumbidgee relied on melting snow from the southern Alps for its water; fortunately the melt water arrived in the river just after shearing when the wool was ready to be moved. In years of light rain and snow on the Alps the paddle-steamers may have only three to four weeks of suitable water depth instead of the three to four months they usually had to navigate the river. In 1858, Randall's *Gemini* reached Hay before the water became too shallow, later that year during higher river levels in the spring they reached Gundagai but that was beyond the practical limit of navigation which was initially accepted as Wagga Wagga then, with time, revised downstream to Narrandera then Darlington Point (Glencross-Grant 2009). Along the Goulburn River the navigation limit was found to be Shepparton.

On the Darling River the settlements at Menindee, Wilcannia and Bourke were all reached (in 1860) and Randell reached Walgett in 1861, this proved to be the practical limit of navigation on the Darling under best conditions although there are reports that paddle-steamers also regarded Brewarrina, closer to Bourke, as the limit of navigation. A paddle-steamer arriving at Bourke was accepted as proof that the Darling could be a viable transport link with the outside world and transport patterns changed accordingly. Bourke and other settlements along the river immediately became transport nodes where wool was sent from northern New South Wales and southern Queensland to be loaded on paddle-steamers and sent south for export. Similarly, freight from the south was unloaded from paddle-steamers at river ports for forwarding to remote settlements and sheep-stations. When regular traffic started up the Darling River inland river traffic became so prolific that the western river system was colloquially referred to as the “West Coast of New South Wales” (Figure 3.3) (Wannan 1978:114).

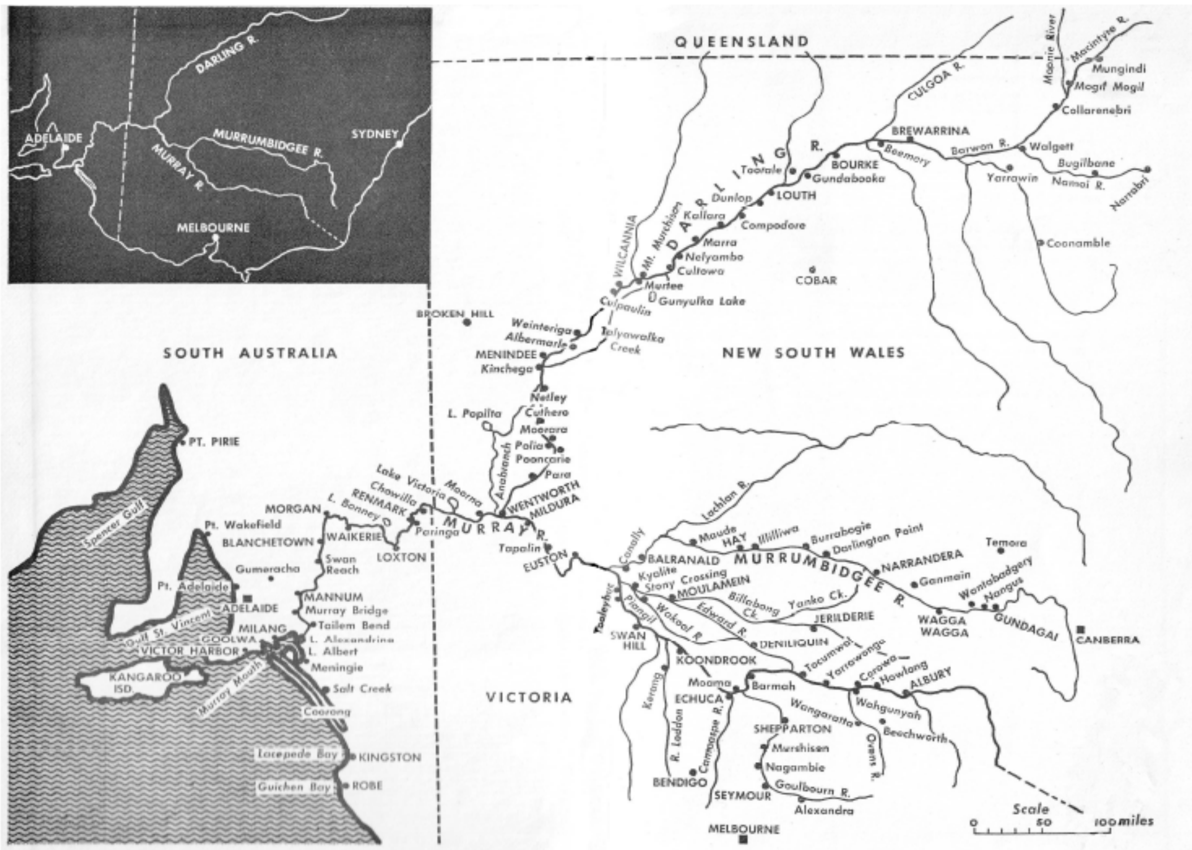

Figure 3.3 Inland waterways of NSW (Source: Mudle 1961)

However, river trade along the Darling was more difficult than on the Murray because of the long distances and erratic river flow. By 1865, paddle steamers were carrying wool and copper down the Darling. The wool industry was the mainstay of the river trade. With new and more powerful steamers and longer and wider barges, the volume of wool transported by paddle steamer increased rapidly.

Water levels in the Darling depended on rain in southern Queensland and northern New South Wales; the Darling varied from a magnificent river with eight to ten metres of water depth, as it was in 1870-1871, to a string of waterholes, as it was in 1885-1886 when seven paddle-steamers en-route for Bourke became stranded and spent fifteen months in the dry river bed waiting for the next rain to release them. One of those stranded was the paddle-steamer *Jane Eliza* which took 3 years between 1883 and 1886 to complete a voyage between Morgan, S.A. and Bourke. Another of those stranded had left Wentworth with building material for a new hotel at Bourke, only to get stranded when the river fell. When the boat finally got to Bourke, the hotel had been built with materials carried to the town by the new railway.

It was surmised in 1895 that:

The Murray River is navigable during the greater part of each year, but the same cannot be said of the Darling, which as a rule can only be used by shipping during the period from March to September (Coghlan 1895a:100).

Inaccessible conditions for paddle-steamers were a particular hindrance to settlers along the Darling where river transport had prompted sheepmen to establish stations along the isolated river. Each station was a calling point for the river trade and the paddle-steamer was their only link with the outside world. Paddle-steamers not only took away their wool clip but also transported their visitors and carried stores; cooking pots, flour, tobacco, beer, galvanised iron, dried fruit, pipes, pickles, kerosene, candles, boots, books, saddlery, perfume, clothing, sewing materials, etc.

Most steamers carried passengers and stores in addition to the wool cargo but there were some specialised floating shops. In 1867 the *Prince Alfred* was built in Goolwa as a floating shop and others vessels followed, the largest was the Merle which towed a barge (*Flo D*) carrying additional stock. In a different line of business, two mission boats (*Etona* and *Glad Tidings*) provided religious services to isolated communities along the river (Younger 1976).

3.2.5 Paddle-Steamers

A few of the stern-wheelers popular on American rivers were in use but most paddle-steamers on the Murray-Darling were side-wheelers which were easier to handle in the swirling currents and tight bends of Australian rivers. A few steamers were imported from America or Britain but most were built in shipyards along the Murray at Goolwa, Mannum, Morgan or Echuca. Local timber, often red gum, was used. Paddle-steamers usually had two decks and were up to 36 metres long, weighing up to 225 tonnes. They were nearly flat-bottomed and had very shallow draught similar to river craft on American rivers but Australian river craft had shallower draught than American vessels because of the low water level so common in Australian rivers. They used wood cut from the river banks to fuel their boilers (Mudie 1961).

Barges were widely associated with paddle-steamers on the Murray-Darling either towed behind or lashed alongside steamers to increase the volume of goods they could transport. Barges were empty hulls with several holds separated by bulkheads. Wool bales were stacked in a pyramid shape with a single row of bales at the top and spaces for pumps which may be needed during the voyage. Each layer of bales was firmly secured with wire cables, so the cargo would not move if the barge ran into a sandbank. Finally the cargo would be firmly lashed down all around.

The barge steering wheel was raised at each successive tier, so that the steersman could see above the cargo (see Figure 3.4). Many barges were handled by one man (Wannan 1978).

3.2.6 River ports

Goolwa benefitted from being the first link between the Murray-Darling river trade and the outside world. With the river opened, and the railway and wharf established, the volume of trade through Port Goolwa (proclaimed in 1857) increased enormously. Paddle-steamers towed barges carrying supplies upriver to pastoralists, to the Victorian gold-diggings and to newly-established towns, and returned laden with wool for export. The town grew and prospered. Extensions to the Goolwa wharf were soon necessary and ship-building began with Goolwa being the first Australian river port to have a ship-building industry. The first vessels were built in 1853 but the main ship-building and repair yard, Goolwa Iron Works, opened in 1864. The Iron Works incorporated a slip in the river and an iron foundry producing ships and engines as well as railway trucks and other machinery and casting (Wannan 1978).

Goolwa's monopoly of the river trade began fading when the Victorian government decided to capture some of the river trade and railway line from Melbourne reached Echuca; the first train arrived in October 1864 and wool had been received at the Echuca terminal since August of that year. Echuca Wharf was built between 1865 and 1867. Wool from pastoral properties along the rivers far into New South Wales could now be taken to Echuca Wharf, transferred from paddle-steamers onto trains then taken to Melbourne for export. Echuca offered the lowest-cost way of sending wool from sheep station to ocean port and grew rapidly as a river port. The wharf was extended in 1877 and again in 1879 to reach a maximum length of 332 metres (Younger 1976).

Figure 3.4 Wool barge at Echuca Wharf, NSW, undated. Note steering wheel at top of barge at left. (Source: P.J. Phillips Collection, N.L.A)

The 1870s was a period of substantial growth in the wool industry in New South Wales when the wool clip grew from 33,500 tonnes to more than 72,500 tonnes (Buxton 1967). Most of the sheep producing that wool were in the Murray-Darling Basin; by now sheep had spread into the northern reaches of the Darling so that outback New South Wales was akin to one vast sheep run with the Riverina as the industry stronghold. As the wool industry prospered so too did the river-boats. Paddle-steamers carried every imaginable item for outlying stations and for more remote settlements but wool bales for export remained their primary business and main source of income.

For the period for which records were kept of Darling and Murray River ports, there was a total of 42,800 tonnes inwards in 1886, which increased to 88,600 tonnes in 1894. The total for the period 1886-94 was 519,000 tonnes (an average of about 65,700 tonnes/ annum) (Coghlan, *ibid*). By 1890 there were some 140 steamers running regular schedules on the great inland rivers (Wannan 1978:3).

As a consequence of the inland river traffic, opening bridges had to be constructed at various strategic locations. Movable span bridges were erected during the period 1874-94 over the Murrumbidgee River at Hay (1874) and Balranald (1883); the Darling River at North Bourke (1878) and Brewarrina (1888); and the Murray River at Wentworth (1893).

The South Australian government was not prepared to see Echuca in Victoria dominate the booming river trade unchallenged and established a new river port at Morgan with direct rail connection to Adelaide. This river port was intended to capture more river trade, especially from the Darling River since Morgan was considerably closer than Echuca to the junction of the Murray and the Darling and promised faster transport of wool. The town of Morgan was surveyed in 1878 and in April of that year the first steam locomotive made a test run from Adelaide on the new railway line. River trade at Morgan was slow to begin but then grew quickly. Within a few years six trains a day were running between Morgan and Adelaide and the five steam cranes on the wharf were operating 24 hours a day transferring cargo between trains and paddle-steamers alongside the wharf (Younger 1976).

3.2.7 Competition from the Railways

The period 1872 to 1884 was boom time for the economy in the Australian colonies around the Murray-Darling; the wool industry, with its partner the river trade, was part of that boom. But the rail network was spreading and would soon diminish the river-trade. Few people foresaw that change and in 1874 the Port of Echuca recorded its busiest year ever with 240 boats trading with the port (Wannan 1978).

In the same year the Victorian Government opened the final section of a railway line from Melbourne to Wodonga. Paddle-steamers previously carried freight to and from Albury and Wodonga via Echuca; now that commerce went by rail directly from Wodonga to Melbourne and the river trade lost business.

The New South Wales Government had watched the growing wool industry and river trade with concern. New South Wales sheep stations were producing more and more wool each year and it was going to build up ports and businesses in Victoria and South Australia.

Worse, many parts of the Riverina looked more to Melbourne than they did to Sydney because they conducted business with Melbourne via the river trade and Echuca. A programme of building railway lines to connect the sheep growing areas with Sydney was begun to provide competition to the river trade. Developments on the main southern line were incremental; from Goulburn the line went to Yass, then Cootamundra, then Junee, Wagga Wagga and Gerogery (reached in 1880) but not quite to Albury in case that encouraged trade between southern New South Wales with Victoria. A branch line from Junee went along the Murrumbidgee to Narrandera (in 1881) and then Hay, which was considered in Sydney to regard itself as virtually a Victorian town. The effects were immediately noticeable at Hay:

Prior to the railway in 1882 the swing bridge at Hay opened for as many as 6 paddle steamers per day. Conversely, in the whole of 1883 only six steamers passed through (Buxton 1967:217). River traffic was now rapidly on the decline and rail transport had taken over, or soon would.

A railway extension from Narrandera went to Jerilderie. To the west the train line from Bathurst was extended to Condobolin on the Lachlan River and from Orange, north to Dubbo on the Macquarie River and finally to Bourke in 1885. Now New South Wales could capture the pastoral trade previously carried along the Darling to Melbourne (via Echuca) and Adelaide (via Morgan) and divert it to Sydney. Paddle-steamers lost more business.

In South Australia a spur from the Adelaide-Melbourne railway line was laid to the wharf at Murray Bridge and the Port of Mobilong declared in 1886. A two level timber wharf 190 metres long was available for paddle-steamers. Murray Bridge as a working port meant the end for Goolwa and Mannum as river ports; trade through Goolwa had virtually ceased by 1890. About that time train lines were built to Loxton, Waikerie, Paringa, Berri and Renmark, Barmera and Glossop - all places which had relied on the river trade and now used the railway. Several of these South Australian places, and Mildura in Victoria, produced dried fruits which paddle-steamers carried to the nearest railhead. But the growth of irrigation was also seen as a threat to river-trade because irrigators continued pumping water out of the river during dry seasons reducing water depth further when it was already too low for safe navigation.

3.2.8 The Boom ends

The boom time had faded by the 1890s. In one year the Port of Echuca recorded 74 boats leaving the port after recording 240 in 1874. The reduced wool clip during the 1880s drought and the 1890s national economic crisis made life difficult for everybody, but river trade was also badly affected by competition from the growing network of railway lines offering a lower-cost and more reliable service to pastoralists than was possible from paddle-steamers limited by water depth in rivers. Motor vehicles were also threatening the river-trade, though by 1895 the major roads had lost their former importance and the situation could be summarised as:

The railways of the Colony for the most part follow the direction of the main roads, and attract to themselves nearly all the through traffic. The tendency now is to make the roads act as feeders to the railway, by converging the traffic from the outlying districts towards convenient stations along the line (Coghlan 1895b:704).

But the river-trade was far from dead and paddle-steamers continued carrying freight and passengers, especially to places such as Mildura and the lower Murray River which did not have a railway connection with Melbourne until 1903. Tourist trips became more popular, often linking rail heads with paddle-steamers; one example was a tourist trip from Melbourne to Echuca by rail, paddle-steamer from Echuca to Morgan, train to Adelaide then return to Melbourne by coastal vessel.

A particularly prolonged drought from the late 1890s until 1902 so badly disrupted irrigation and river traffic that the states met to discuss 'drought proofing' the Murray. By 1915 they had agreed to build a series of weirs and locks to manage the flow of the river for navigation and irrigation. But river traffic was declining and in 1924 the agreement was amended to give higher priority to irrigation requirements than to navigation. In 1934 the agreement was further altered to provide for only 14 locks instead of the original 26. Paddle-streamers assisted in construction by carrying cement, crushed granite and other building material to the construction sites.

After Locks 1 to 11 were completed in the late 1930s the Murray was navigable in years of normal rainfall from the Mouth to 100 kilometres upstream of Mildura. But the river trade had dwindled to insignificance; the Port of Echuca had so few movements that record keeping ceased in 1910. The last profitable riverboat trading area to Echuca was on the Edward River and the Lower Murrumbidgee to Balranald. Railways from Victoria tapped this trade when lines were constructed to Moulamein in 1925, Balranald in 1926 and Stoney Crossing on the Wakool in 1928 (MBK, 1998:16).

The last commercial river-boat left Bourke in 1931. There was still some activity around Murray Bridge with bagged wheat carried in the 1920s and 1930s and local movement of milk from dairies along the river to the milk factory downstream of Murray Bridge wharf. Around Echuca there was some local logging-related river activity until the mid-1950s, but the river trade as a whole had ended decades before then.

In summary, the river trade grew from a very small beginning into a substantial enterprise because it provided better transport service, at lower cost, than bullock wagons. Pastoralists growing wool on properties along the Murray and Darling Rivers relied on paddle-steamers to move their wool clip and the paddle-steamers relied on the income from carrying wool to remain profitable. Despite problems with variable water levels in the rivers, and difficulties caused by competition between the three colonial governments concerned, the river trade thrived while paddle-steamers provided the best service available to pastoralists (Younger 1976).

In the late 1850s, South Australia planned to funnel the Murray River trade down the Murray River and associated River systems to Goolwa from the Goldfields of Victoria. This was foiled by the entrepreneurs in Melbourne connected to the Black Ball shipping line, and the Bright family, who started to develop the "Melbourne Mount Alexander and Murray River Railway" to Bendigo, Echuca and beyond. They were unable to borrow capital, so the Victorian Government took over and built the railway to Bendigo and Echuca, establishing the major port of Echuca, turning the River trade around, so that the river boats sailed down the Darling and the Murrumbidgee to the Murray, then upstream to Echuca. This then set a pattern of funnelling the goods of inland Australia down to the Port of Melbourne.

NSW Government tried to retrieve the situation by building railways out to places like Wagga Wagga, in an attempt to capture the trade. The expanding rail network took business previously handled by river traffic and soon paddle-steamer operators were going out of business. However, once road transport took hold, the trade continued to funnel goods from inland NSW and southern Queensland down the Newell Highway, on to the Port of Melbourne.

But the growing railway network offered a more reliable, faster service to pastoralists and to the general community. Paddle-steamers replaced bullock drays because of better service and the paddle-steamer was replaced by the railway because the train offered still better service.

Fraser (1990) has previously drawn attention to the importance of the north-south inland travelling stock routes during this period, whereby sheep and cattle destined for frozen meat to England travelled from central Queensland to Melbourne rather than crossing the Great Dividing Range to Sydney. This easy direct route to overseas shipping is still popular with heavy semi-trailers today.

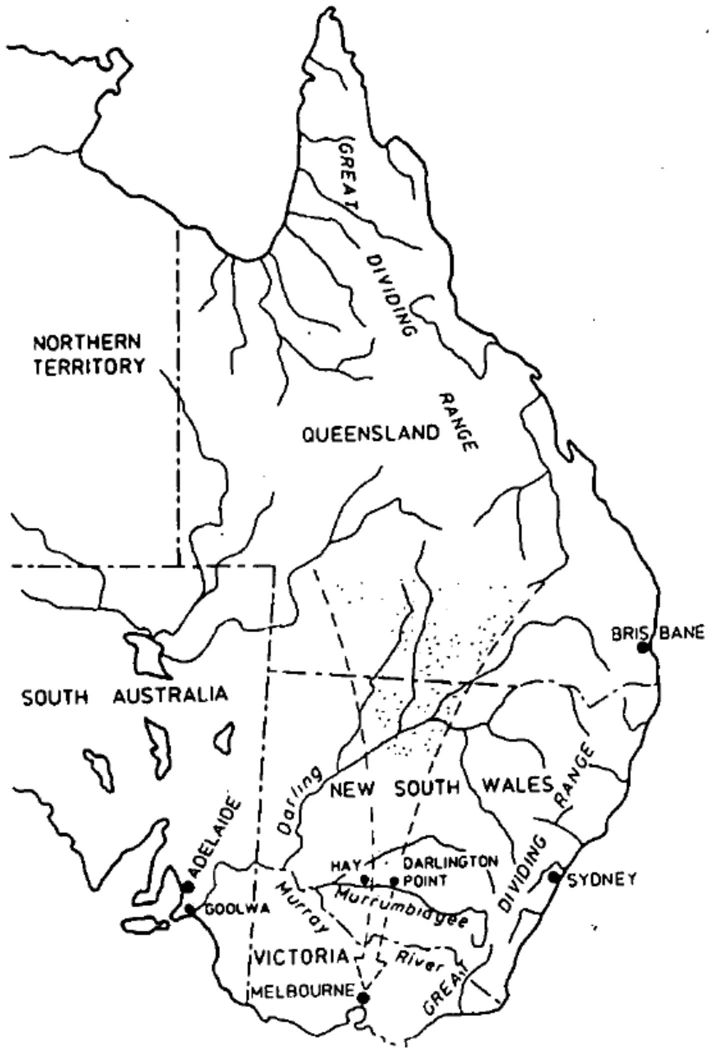

Figure 3.5 Inland travelling stock routes between central Queensland and Melbourne; a key focus of interstate riverboat competition (Source: Fraser, 1990)

As a postscript from the 1970s a new generation of tourist cruise-boats came into operation ensuring the continuation of the navigation tradition on the Murray River. These include completely new purpose-built vessels and restored paddle-steamers. The oldest paddle steamer still in regular use on the Murray River is the P.S. *Adelaide* which was built in 1866.

3.2.9 Northern rivers

The Clarence and Richmond Rivers in their earliest use first provided access to cedar and its transport to market and secondly to export wool from the Tablelands. From 1838, when the *Susan* took out the first cargo of cedar to 1850 when a fleet of sailing ships carried on a significant trade between the Clarence and Sydney, the shipping trade itself had assumed some importance. The *Susan*, *Elizabeth*, *Taree* and *Eliza* were the first vessels used in this role and were described as schooners. The *Susan* made 115 trips before being wrecked in 1850. Some of the schooners were built locally so shipbuilding could be called the first industry on the Clarence River. The dairy industry commenced at this time was unsuccessful but was to become very important later.

The first paddle steamer *King William IV* arrived in May 1839. The transfer from sail to steam was a very gradual process and sailing ships continued in use for commerce on the Clarence River well into the 20th century.

By the 1890s the nature of the cargoes departing from the Clarence and Richmond Rivers had diversified and included, besides timber and wool, gold, tin, corn, sugar, bones and horns, tallow and hides. As far as the people were concerned the river dictated a great deal to their way of life, not only in earning a living but socially as well. A boat, be it a rowing boat or a river steamer, was necessary for trading, schooling, a visit to a friend or a doctor or attendance at church. As roads improved horse drawn vehicles came into their own to be succeeded by the motorcar (Gardiner, 2006, p.35)

On the Clarence River commuter services ran between Grafton and Yamba from the 1880s and as the traffic increased steamboats with larger engines, a cabin and decks provided a more comfortable trip. The last boat in this role was withdrawn in 1941 by which time faster road transport had taken over almost all the passenger and most of the cargo traffic.

Figure 3.6 The *Woolwich* which was one of the larger commuter vessels in use from 1922 onwards

On the Northern Rivers much of the trade was undertaken by droghers. These were slow, shallow, often punt-like steamers propelled by a single paddle wheel placed at the stern so that it could tie up close to the banks when loading produce from farms that had no wharf or jetty.

John McFarlane (1854-1910) who was a produce agent as well as a Member of Parliament and after whom the McFarlane Bridge was named gave the following summary of the use and importance of droghers:

The advent of the drogher supplied a want that was much appreciated by the settlers and induced them to take up land on the different arms, channels and tributaries where it was impossible for ocean steamers to ply but could without difficulty be negotiated by the droghers. They were of shallow draught, being flat bottomed, and were usually driven by a stern wheel and consequently well fitted for serving the small rivers and creeks.

The first drogher to be built locally was the PS (Paddle Steamer) Settler's Friend built in Ulmarra and the best known was the Perseverance which remained in use until 1944.

Cream boats were a more specialized form of droghers in that they were generally smaller and faster but also needed to be manoeuvrable to pull in to many small wharves and jetties. They worked to a timetable to get the cans of cream to the butter factories as soon as possible and served a useful purpose in delivering newspapers and other items and had to work in all weathers(Gardiner, 2006, p.45)

With the decline of shipping as a transport mode, owing to better roads and rail, and the closing of the North Coast Steam Navigation Company (the major shipping firm of the area) in 1954, the river became less important as a port.

4. Vertical lift span bridges

4.1 Description of vertical lift span bridges

Vertical lift span bridges are movable bridges which rise vertically and remain horizontal throughout operation. The first generation of vertical lift span bridges in Australia are of particular interest as there is a fascinating evolution in designs, with a number of distinguished Australian engineers contributing to the body of knowledge of each subset.

Characteristic components of vertical lift bridges include towers supporting a sheave at each corner of the opening span, counterweights to minimise the force required for operation and subsequent ropes or chains which pass from the counterweight over the sheaves and attach onto the lift span.

There are a number of advantages for vertical lift bridges noted by Hovey (1926) and they include:

- When the bridge deck is high above water level a low lift will allow the passage of vessels.
- There is the ability to partly raise the bridge for smaller vessels.
- If the bridge is built on an alluvial soil where the channel is likely to shift, an allowance for changing the movable span can be introduced by adding towers to adjacent spans and moving the mechanism when required.
- Parallel bridges can be readily added to cater for growing vehicular traffic.
- Minimal obstruction of the waterway.

The disadvantages of the vertical lift span bridge include the limited headway depending upon tower height and the difficulties encountered when there is a need to maintain, repair or renew components.

Vertical lift bridges are categorised by the arrangement of the span drive machinery and superstructure geometry. There are four representative sub-types of vertical lift bridges including the wire rope span drive, tower drive, connected tower drive and lastly the pit drive (table bridge).

4.1.1 Tower span drive vertical lift

Span drive vertical lift bridges are typically a balanced vertical lift system. The lift span ends are attached to wire ropes that pass over the sheaves mounted at the tops of the towers. The ropes then attach to counterweights at the opposite end of the rope. The counterweights typically balance the weight of the lift span, however for large lift bridges the magnitude of the counterweight ropes create a significant weight differential, as the ropes pass from one side of the sheave to the other. This differential is often balanced by an auxiliary system to mitigate power requirements for the operation of the span (WisDOT, 2011). The principle types of span drive vertical bridges include wire rope span drive and rack and pinion span drive.

Wire rope span drive

The defining feature of a span drive bridge is the wire rope drive mounted on the lift span that hauls the span upward or downward. Figure 4.1 shows the directions of rope travel for the lift span being lowered. The noteworthy advantage of this type of drive is the mitigation of longitudinal skewing, the continuous connection of haul ropes prevents one end of the lift span rising faster than the other, which would result in jamming the span. In Figure 4.1 the hoist drum is located at mid-span, however span drive bridges exist for which the primary drive machinery is at mid-span and the secondary machinery and hoist drums are located at the ends of the span. (WisDOT, 2011).

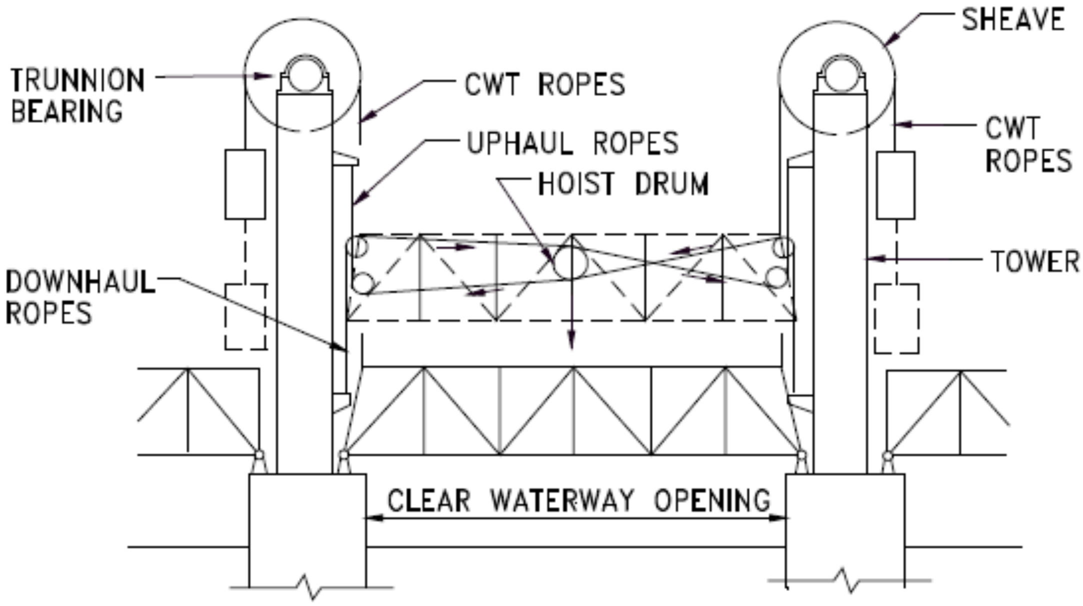

Figure 4.1 Wire rope span drive (Source: WisDOT, 2011)

Rack and pinion span drive

In place of haul ropes to operate the drive machinery, rack and pinions are another common drive system. These bridges are still balanced throughout operation. The primary driving mechanism is located at the centre of the lift span and the secondary machinery is located at each end of the span. Operation is achieved through pinions engaging racks that are mounted vertically on the towers, with rotation of the pinions raising or lowering the span. This type of drive has been known to result in significant longitudinal skewing of the lift span (WisDOT, 2011).

4.1.2 Tower drive vertical lift

Tower drive vertical lift bridges are balanced bridges which have drive machinery located at either the top or base of the towers. The two basic types include traction drive and winch drive bridges. The characteristic feature of tower drive vertical lifts is that the machinery in one tower is mechanically independent of that in the other tower.

This often results in differential rising of the span ends, thus requiring the implementation of mechanical or electrical controls to limit this differential (WisDOT, 2011). The principle types of tower drive vertical bridges include wire rope traction drive and winch drive.

Wire rope traction drive

Figure 4.2 presents a schematic of a tower drive vertical lift bridge with a traction drive. Drive machinery located at the top of each tower rotates the counterweight sheaves. The forces necessary to raise the span are then transmitted from the sheaves to the counterweight ropes by friction. It is noteworthy that the force necessary to raise the lift span at each end may differ due to unequal machinery friction, differential span loading and the temporary effects of rain or ice.

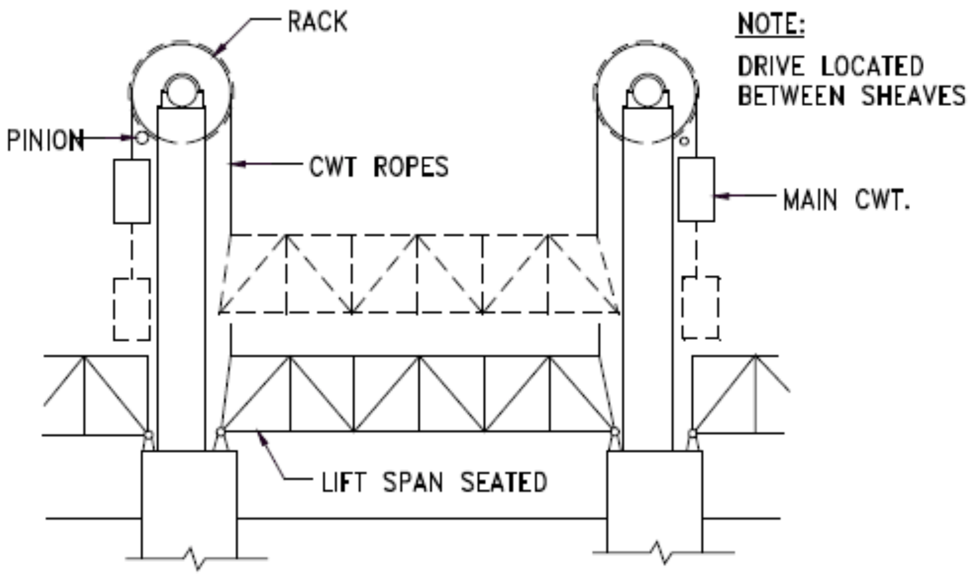

Figure 4.2 Tower drive (Source: WisDOT, 2011)

Winch drive

Winch drives are another variant of tower drive bridges. The lift span is balanced in an identical fashion to previously noted bridges, however the power to operate the span is provided by winch drives that are commonly mounted in the base of the tower. Haul ropes are connected to either the lift span framing or to the counterweights, with the rotation of the winch recoiling the wire ropes thus raising the span. As with the traction drive variation, because the mechanical machinery on one side of the channel is independent of that on the other side, skewing has to be controlled (WisDOT, 2011).

4.1.3 Connected tower drive

Connected tower drive vertical lift span bridges are those bridges with have longitudinal and lateral framing which connects the tops of the towers and also supports machinery and access walkways (Figure 4.3). As with other vertical lift bridges the operation is balanced by counterweights. However, since this type of bridge is only suitable for short spans with a moderate lift, the counterweight ropes do not require an auxiliary counterweight system. Span drive machinery is mounted on the top connecting structure. Various machinery arrangements exist with different bridges positioning mechanisms at mid span or adjacent to a sheave.

Driving power is provided by pinions that engage curved racks fastened to the counterweight sheaves. The force necessary to move or hold the lift span is transmitted between the sheaves and the counterweight ropes by friction. Alternate driving mechanisms with wire ropes connecting the sheaves, to transfer rotation to each end, of the bridge also exist.

As all the span drive machinery is directly connected skewing of the lift span in either the longitudinal or transverse direction is mitigated. However, minor skewing due to differential counterweight rope stretch, different sheave diameters, and rope slip in the counterweight sheave grooves may cause skewing over time (WisDOT, 2011).

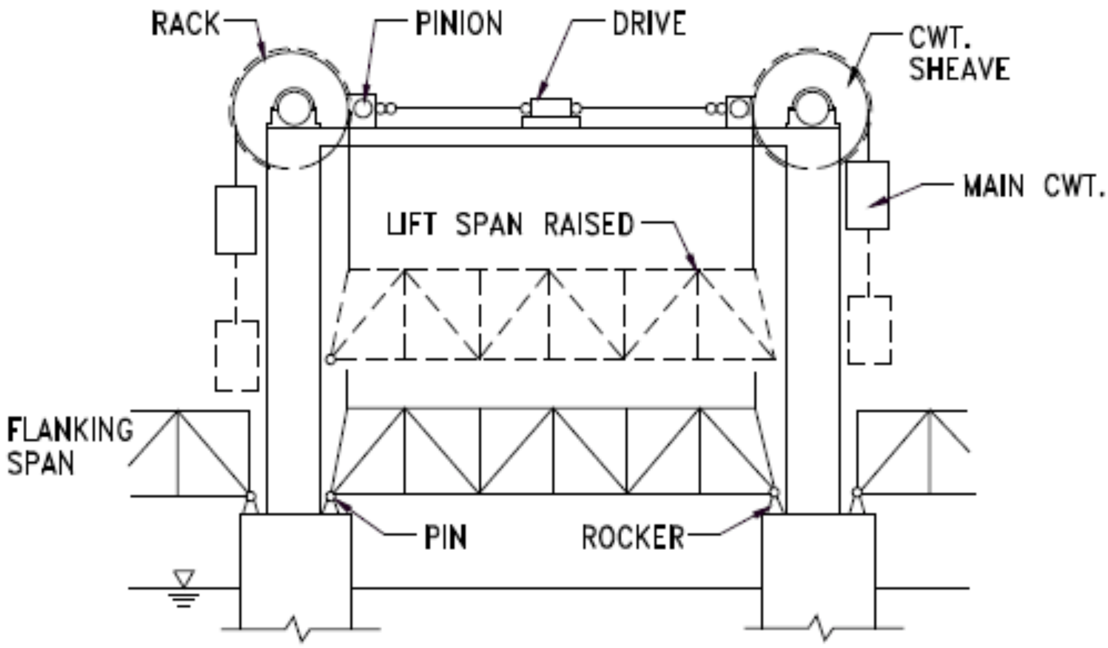

Figure 4.3 Connected tower drive (Source: WisDOT, 2011)

4.1.4 Pit drive vertical lift span or table bridge

Table bridges are those bridges which remain vertical during operation and are powered by hydraulic cylinders that are largely hidden from view when the bridge is in the closed position (Figure 4.4). It is noteworthy that table bridges have also been referred to as pit drive vertical lift bridges due to the location of the driving mechanism (WisDOT, 2011). The defining feature of table bridges is the lack in visual presence of mechanical components and supporting superstructure. Select table bridges are still fitted with supporting counterweights and sheaves to reduce the effective weight that must be raised; however these features appear to be less frequent as this style of bridge evolved.

Table bridges are constructed when the cost of the greater lifting capacity required, compared to a balanced bridge, is estimated to be less than the cost of counterweights or for aesthetic constraints. The hydraulic cylinder drives are most suitable for providing the power for operation because large actuating forces can be produced using smaller electric motors than would be required for mechanical drive. There is also less friction between the prime mover and the point of force application in a hydraulic system (WisDOT).

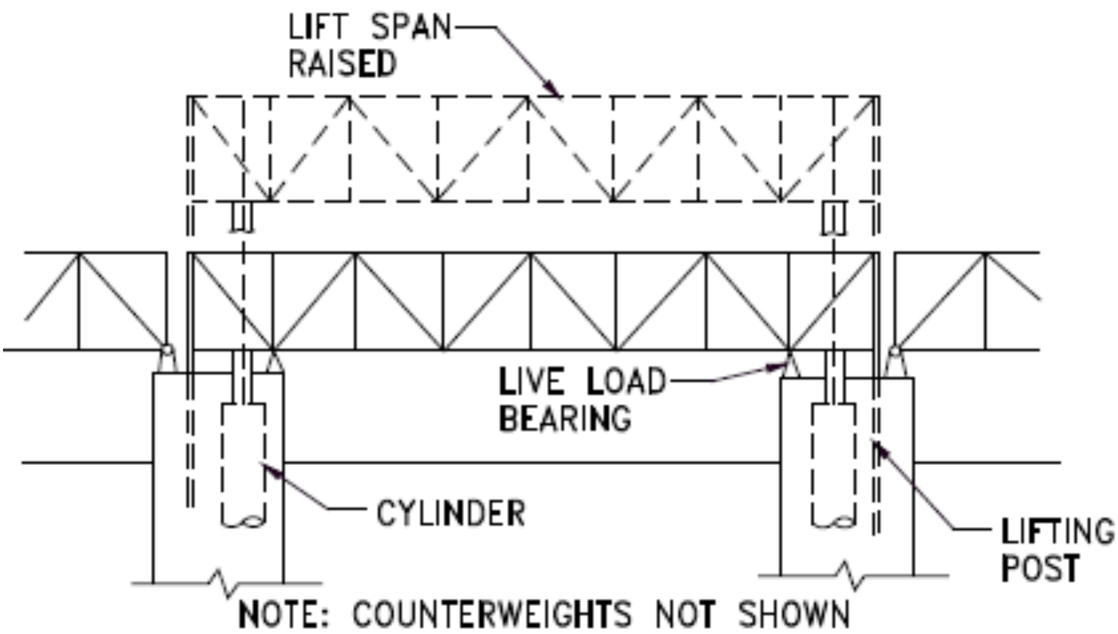

Figure 4.4 Table bridge / pit drive (Source: WisDOT, 2011)

4.2 European origins

The history of the vertical lift span bridges dates prior to 1840, with one of the first bridges over the Danube River at Vienna. This bridge consisted of a 30 ft. opening and could raise approximately 6.5 ft. Another vertical lift bridge was built in the Netherlands at Amsterdam over the Poldervaart canal during 1846, however both of these designs have limited information available and the earliest detailed account is of a vertical lift bridge completed in England in 1848 (Tyrrell, 1912).

The need for this vertical lift span bridge arose in 1846 when the late London and Croydon Railway Company wanted to connect its main line with the river Thames line at Grove Lane Dock. The connection line was to be only 1 mile in length, however it required crossings over the Grand Surrey Canal. The Parliament passed an Act in the same year approving the new line though it was stipulated in the Act that no more of the Canal Company's land should be taken than was absolutely requisite for laying down the new rails.

These stringent requirements rendered the implementation of a swing-bridge unacceptable as the counterpoise of the bridge would occupy excessive amounts of land. The "telescope" type bridge and "bascule" type bridge were also considered, however the telescope type also occupied excessive land and the bascule type appeared less advantages for both efficiency and economy (Hood, 1850).

The design that met the fore mentioned requirements, proposed by R. J. Hood, was a new type of movable bridge which he generally named a "vertical lift bridge" (Figure 4.5). The design broadly consisted of a platform that was to be suspended at all four corners by wire ropes which pass over pulleys fixed on four pairs of cast-iron standards. Hand gearing, shafts and counter weights were the components of the mechanism that would cause the lift motion with the mechanical advantage of twenty six times achieved by the design (Hood, 1850).

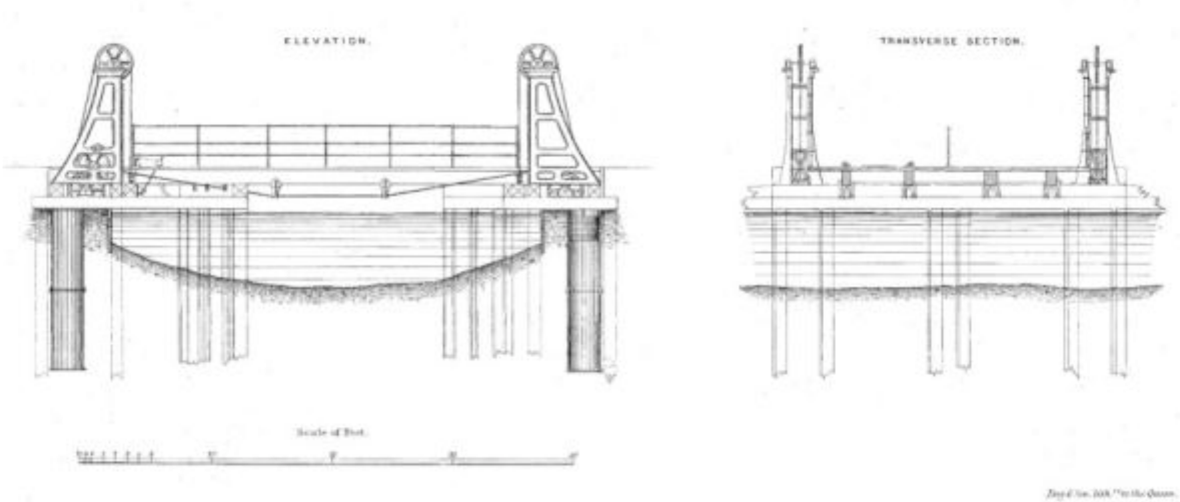

Figure 4.5 First design of vertical lift bridge (Source: Hood, 1850)

Due to unknown circumstances, the original bridge was removed within 10 years of completion and was replaced by a second generation vertical lift bridge also designed by R. J. Hood (Figure 4.6 and Figure 4.7).

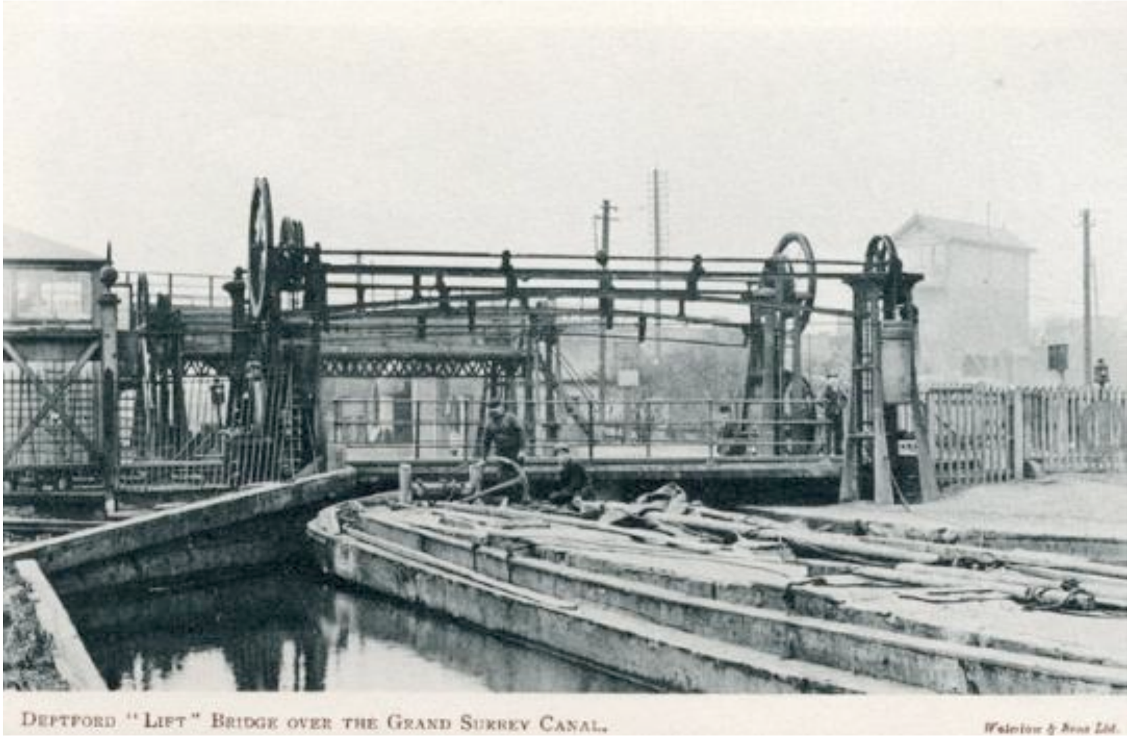

Figure 4.6 Postcard of the second design of vertical lift span bridge over the Grand Surrey Canal (Source: unknown)

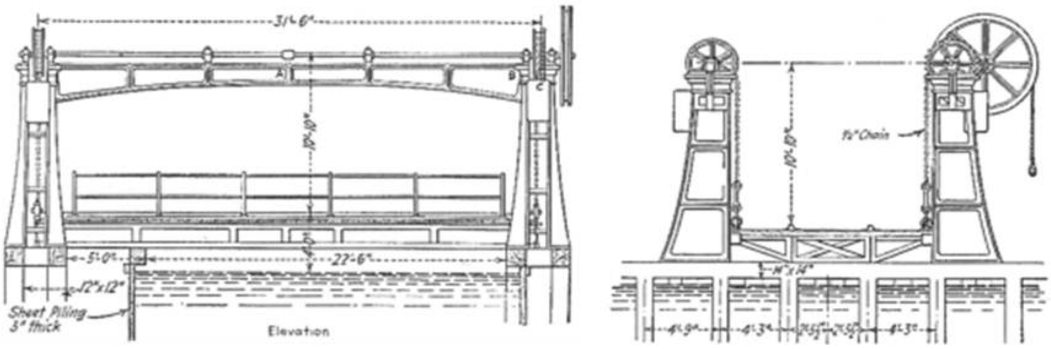

Figure 4.7 Second design of vertical lift bridge (Source: Humber, 1857)

The origins of table bridges cannot be accurately determined however the hydraulic press was invented in by Joseph Bramah in 1796 and as early as 1840 William Armstrong developed a practical application of this principle when he invented the hydraulic crane, with key components being a ram and cylinder. As technology continued to advance the hydraulic technology became more reliable and was adapted to numerous mechanical devices (Gibson, 2009). Some examples are the hydraulic lift grave docks dating to 1856. As evident by Figure 4.8 the docks had numerous hydraulic rams that were used to raise the platform once a ship was position above (Fowler, 1866). From this basis it is likely that adapting this concept to movable bridges would soon follow.

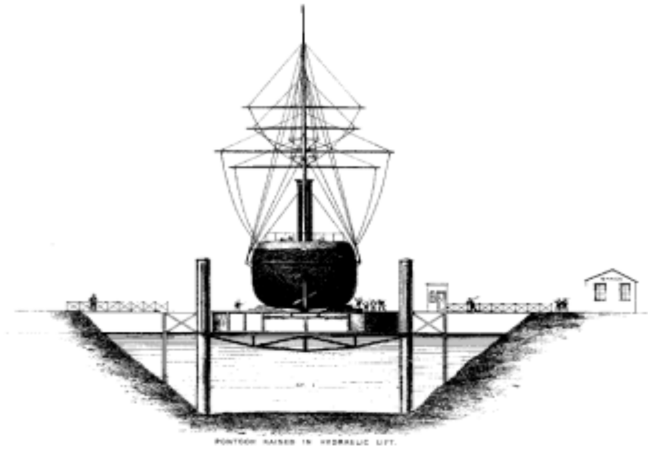

Figure 4.8 Pontoon raised in hydraulic lift (Source: Fowler, 1866)

Early table bridges began to appear in France in the late 1880's with the construction of the Pont De La Rua De Crimee in 1886. It is an impressive structure that is still in operation following small upgrades including the introduction of cables instead of chains. The circumstances surrounding the bridge were noted by French engineer M. L. Le Chatelier in the 1886 Annales Des Pont et Chaussees. The author notes that he was aware of vertical bridge designs from America including their metallic frame work carrying the mechanisms of shafts, pulleys and chains. Chatelier concluded by stating that "the arrangement of these bridges is inelegant from every point of view, and the disposition of the metal which it necessitates cannot be justified either by the momentary course of the movement or the means of employing it." Chatelier continues that the aesthetic tastes of the French public are different and a different design must be created for the bridge over the Canal Saint-Martin. Five-Lille was the only firm to submit a set of plans for such a design and they were awarded the contract (Rafter, 1895). The design consisted of two large hydraulic rams that were positioned either side of the span with counterweights, towers and sheaves still adopted in the design as to reduce the differential weight that had to be raised. The final design is shown in Figure 4.9.

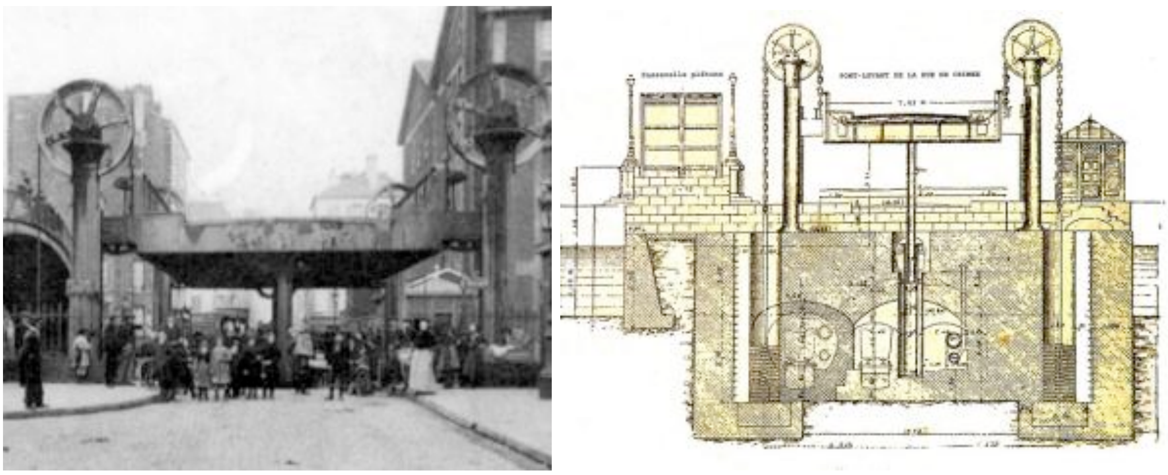

Figure 4.9 Pont De La Rua De Crimee (1886)

As noted previously, even though this initial bridge still used counterweights and sheaves in the mechanism, these were not adopted for all table bridges. Subsequent designs, such as the Pont Levant De Larrey built in 1890 consisted of four conspicuous hydraulic rams positioned at each corner of the movable span (Tyrell, 1912). When lowered is bridge is barely noticeable as a movable bridge, with the location of the hand rails on the pedestrian path being one of the only indicators. This was also an interesting feature of the design which had two levels for pedestrian access, allowing for their continual usage of the bridge in both positions (Figure 4.10).

Figure 4.10 Pont De Larrey (1890)

The use of hydraulics in movable bridges, as evident by these early designs, was reasonable frequent and further mentions of their adoption are highlighted in papers written during the 1890s. Despite this, hydraulic usage began to decline and electro mechanical technology advanced to such a point as to render early hydraulic systems obsolete. Following WWII hydraulic power started to evolve to a point where it could provide reliable and precise control of heavy machinery. The subsequent adaption to movable bridge soon followed and there usage in modern movable bridges has become common (Koglin, 2003). Table bridges of the modern era are evident with examples such as the Pont Levant Notre Dame built in the Belgian city of Tournai (Figure 4.11).

Figure 4.11 Pont Levant Notre Dame in Tournai, Belgium (Source: Karel Roose)

4.3 First generation vertical lift span bridges in NSW

The era from 1840 onwards realised various vertical lift span bridge designs and numerous bridges were built throughout Europe and USA before one of the first vertical lift span bridges appeared in NSW at Balranald in 1882 (Figure 4.12). It is difficult to ascertain how this design was informed, though it is plausible that the designs of bridges over canals in Europe were used as a basis. Reviews of early European designs against the Balranald drawing set do show a number of similarities, specifically with the tower arrangement and sheave orientation.

Figure 4.12 Paddle Steamer passing Balranald Bridge in the 1890s (Source: DMR HO23720)

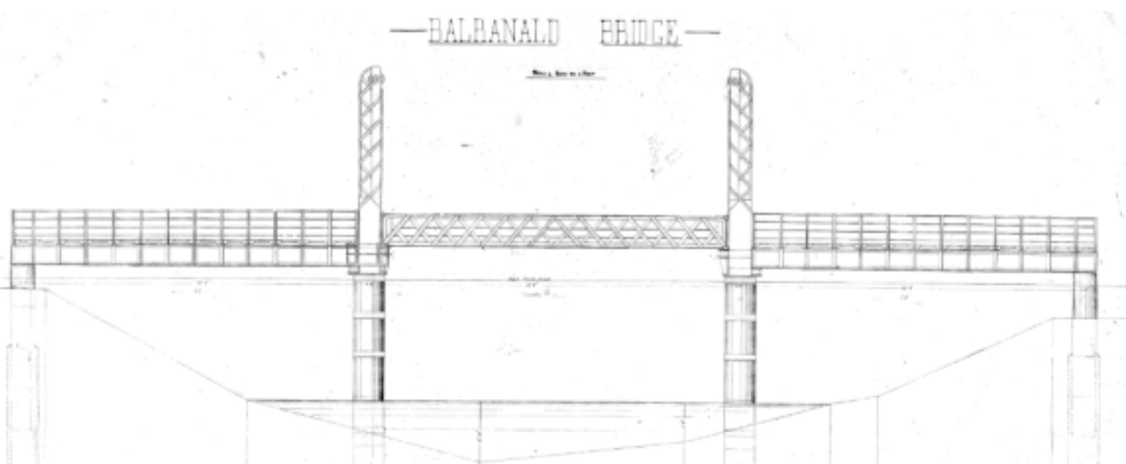

Figure 4.13 Elevation of at Balranald Bridge – 1882

The first generation designs were continually improved upon and a number of ingenious modifications were implemented by different Australian engineers over this early period. The following is a summary of this evolution of designs, the issues that were encountered and how they were overcome by each successive vertical lift span bridge.

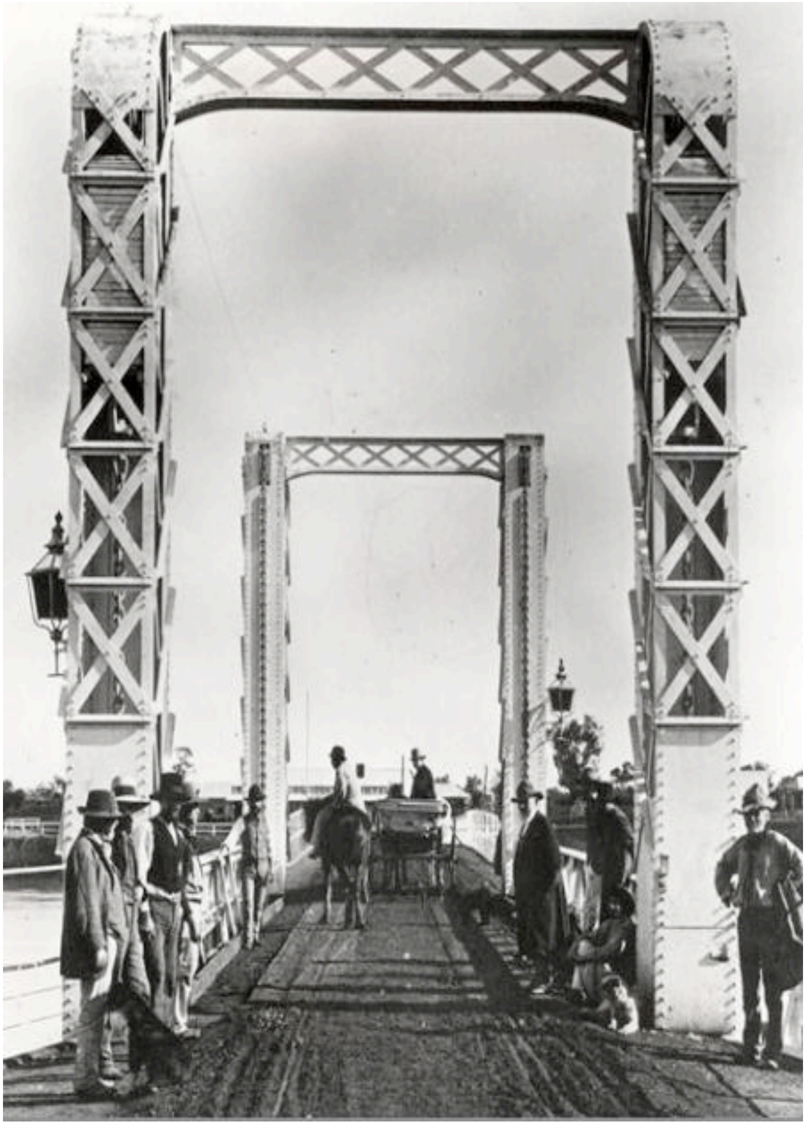

Figure 4.14 Formal opening of North Bourke Bridge in 1883 (Source: DMR HO23716).

The Balranald Bridge completed in 1882 and designed by J. H. Daniels was a wrought iron lattice bridge with independent towers and longitudinally orientated chain wheels. This design proved problematic with the towers deflecting inwards and pinching the lift span. In addition the lifting mechanisms at each end of the span were independently operated which created difficulty in achieving a uniform lift making jamming more susceptible during operation. This design was also adopted for the North Bourke Bridge built in 1883 (Figure 4.14 and Figure 4.15) and modified in 1896.

Figure 4.15 Current view of North Bourke Bridge detailing lateral bracing and stiffeners installed in 1896 (Source: RMS)

These two bridges form the first subset of vertical lift span bridges in NSW and are hereafter referred to as the “Balranald Type” (Table 4-1).

Table 4-1 Vertical lift span type 1 – “Balranald”

BALRANALD type lift span bridges	Built	Status	Opening span length
Balranald Bridge over the Murrumbidgee River	1882	Replaced 1973	15.0 m
North Bourke Bridge over the Darling River	1883	Extant	15.1 m

In order to improve operation, Percy Allan incorporated some modifications into the design of the Brewarrina Bridge completed in 1888 (Figure 4.16). The modifications were simply to add longitudinal girders to the superstructure, therefore minimising differential deflections and to connect the chain wheels by shafts. This design was an enhancement, although retaining a dual winch lift mechanism resulted in unsatisfactory performance. Allan's design innovations were limited to this one structure which forms the sole member of the second subset known as the "Brewarrina Type" (Table 4-2).

Table 4-2 Vertical lift span type 2 – "Brewarrina"

In 1896 modifications to the mechanism designed by E. M. De Burgh were installed. These modifications included the introduction of extra chords to the tower braces and replacing the lifting mechanism with a wire rope arrangement. It is noteworthy that the addition of the tower brace chords changed the member to a lattice girder from a Warren type truss girder. The implementation of each type for different bridges went back and forth throughout subsequent first generation designs.

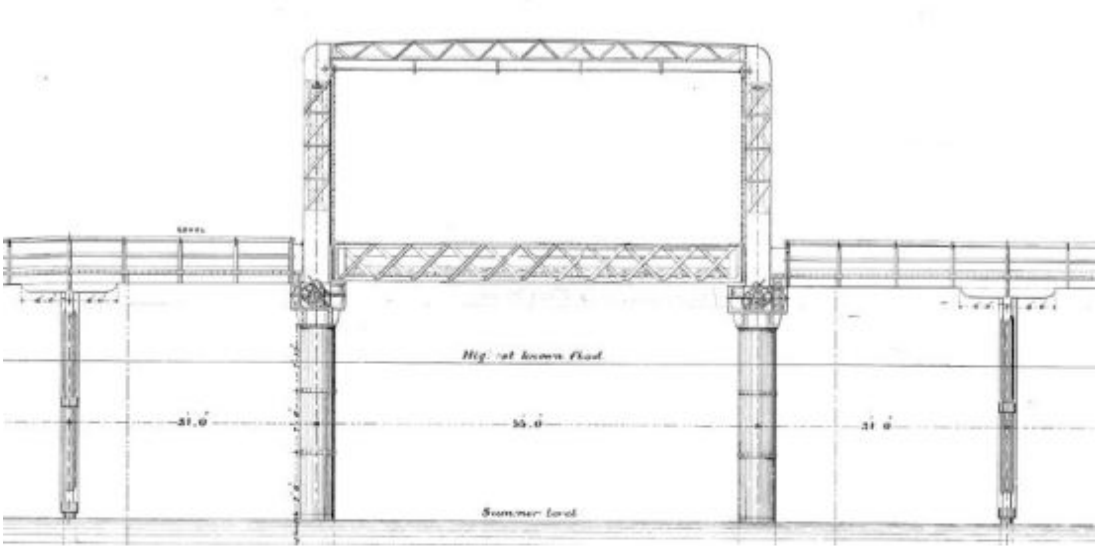

Figure 4.16 Brewarrina Bridge Elevation – 1888

The next progression of design was due to alterations made by J. A. McDonald in his 1893 design of the Mulwala (Figure 4.18) and Wentworth Bridges both built in 1893. These are both described hereafter as the "Mulwala Type" (Table 4-3) forming the third subset of vertical lift span bridges and introduced new concepts which enabled future design and operational improvements.

Table 4-3 Vertical lift span type 3 – "Mulwala"

MULWALA type lift span bridges	Built	Status	Opening span length
Mulwala Bridge over the Murray River	1893	Replaced 1924	14.1 m
Wentworth Bridge over the Darling River	1893	Replaced 1969	14.1 m

This is the first time that wire ropes were used as an enhancement over the chains used previously as this reduced weight and friction in the operating system. Also for the first time the lifting mechanism was designed to be operated by a single person as all the sheaves are linked by shafts thus ensuring a uniform lift. Issues arose with the design due to the weight and overhead location of the winch mechanism causing excessing deflections of the longitudinal girders thus pinching the shafts and inducing additional torsion (Dare, 1896). There were also some issues with the ropes unwinding.

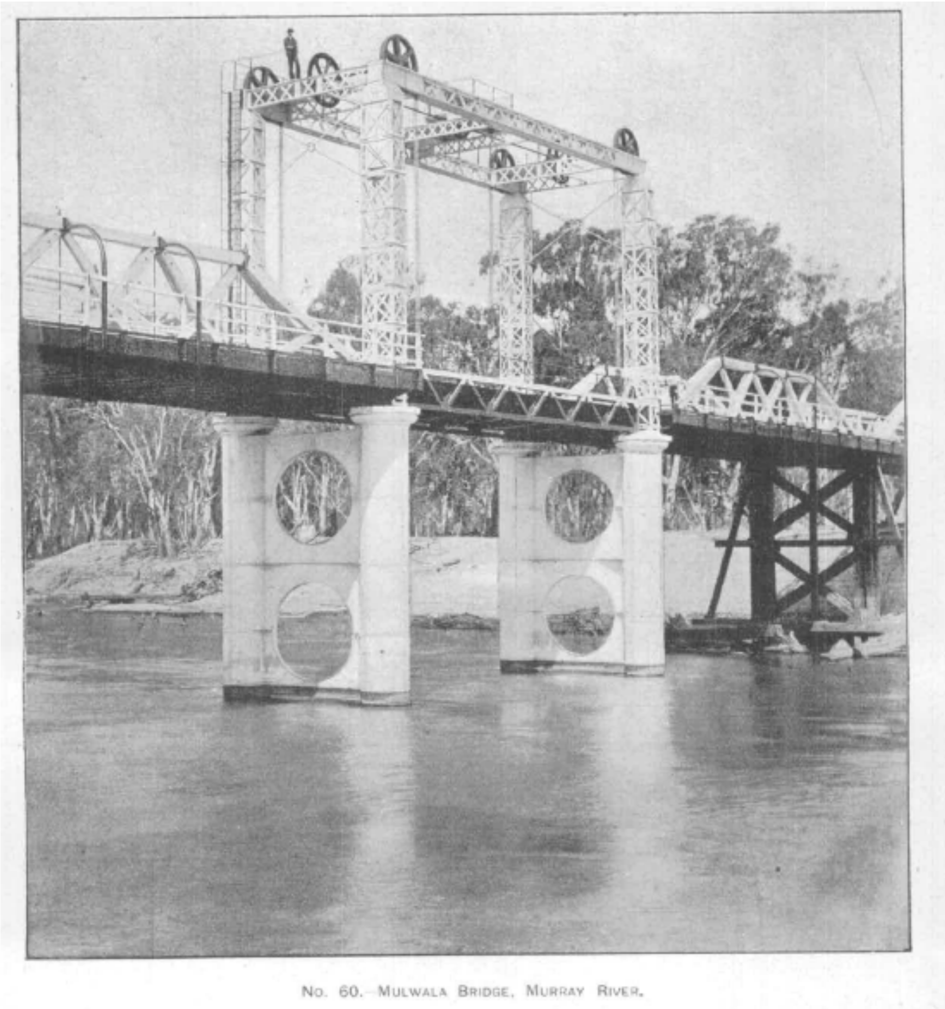

Figure 4.17 Mulwala Bridge shown just after completion with operator at the top of the tower, replaced in 1924 (Source: Annual Report Public Works Department, 1893)

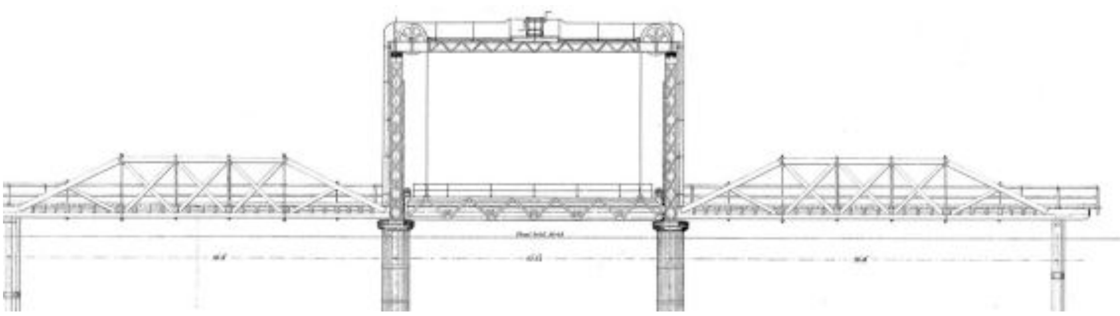

Figure 4.18 Mulwala Bridge Elevation – 1893

J. A. McDonald made a second attempt at improving vertical lift span bridges in 1895 with his design of Tocumwal Bridge (Figure 4.20). The modifications made included changing the direction of the sheaves to be transverse and the counter weights were also hung on the outsides of the towers. Despite these improvements, the shafts were still pinching due to deflections most likely arising from inadequate tower bracing and further enhancements were still required. The Wilcannia Bridge over the Darling River completed in 1896 also adopted a similar design. Collectively these form the "Tocumwal Type" (Table 4-4) as the fourth subset of vertical lift span bridges.

Table 4-4 Vertical lift span type 4 – "Tocumwal"

TOCUMWAL type lift span bridges	Built	Status	Opening span length
Tocumwal Bridge over the Murray River	1895	Replaced 1989	15.4 m
Wilcannia Bridge over the Darling River	1896	Extant	15.4 m

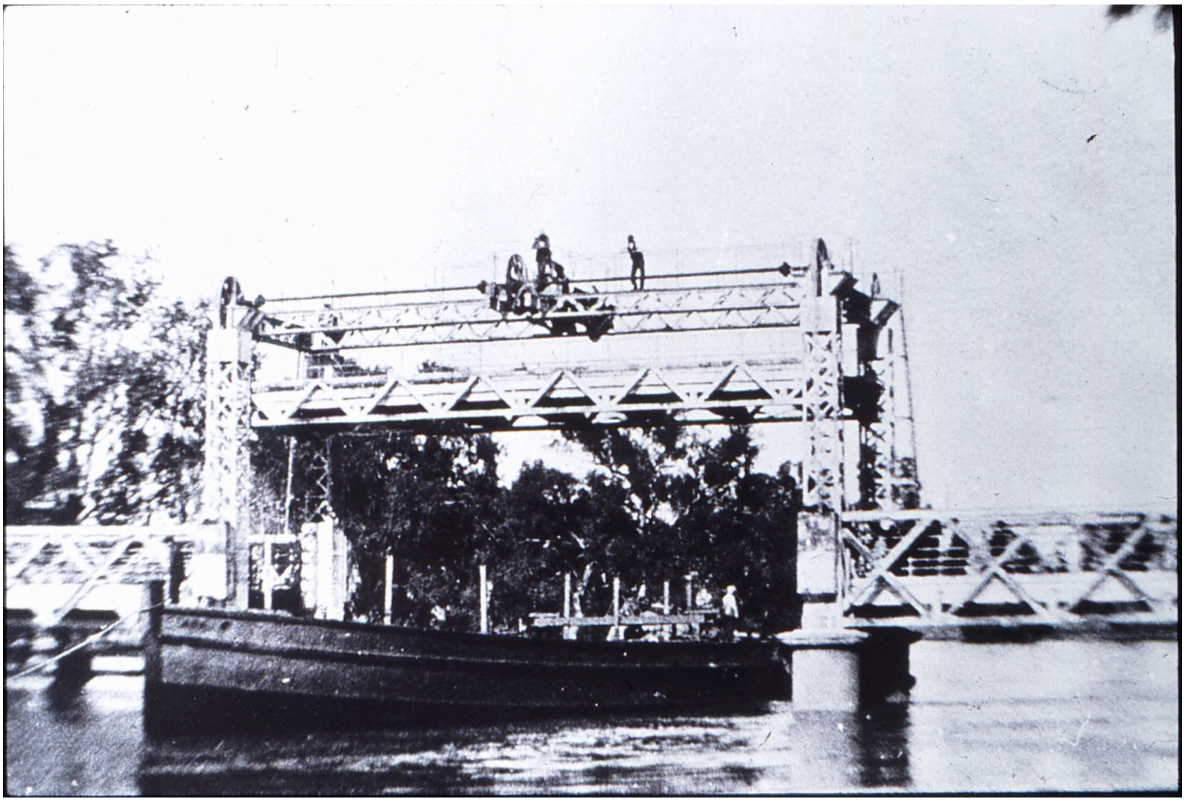

Figure 4.19 View of Wilcannia Bridge with lift span raised showing two operators on the tower, undated (Source: Mitchell Library)

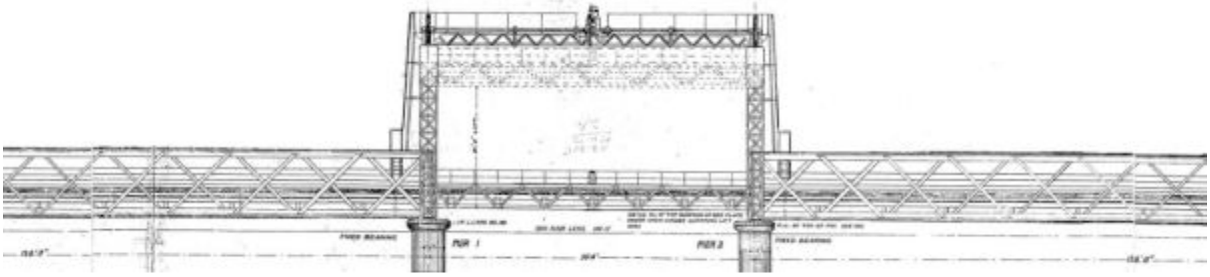

Figure 4.20 Tocumwal Bridge Elevation – 1895

In 1896 the Percy Allan design of Swan Hill Bridge (Figure 4.23) became the most influential of NSW vertical lift span designs. It represents a transition from the designs of J. A. McDonald and it is interesting to note that an alternate set of drawings were created for Swan Hill and signed by J. A. McDonald (Figure 5.15). The design was similar to Tocumwal Bridge however it was never built. The main alterations introduced by Percy Allan were to redesign the lifting mechanism by lowering the previously overhead winch back down to deck level and connecting all sheaves via longitudinal and transverse shafts. These design improvements appear to have prevented the bridge from jamming during operation. This design was adopted for Dunmore Bridge over the Paterson River built in 1899, Tooleybuc Bridge over the Murray River built in 1925, Mildura Bridge built in 1927 and Abbotsford Bridge over the Murray River built in 1928. These four bridges collectively make up the "Swan Hill Type" (Table 4-5) which forms the fifth subset of vertical lift bridges.

Mildura Bridge was dismantled in 1986 following the completion of the Chaffey Bridge. The four steel trusses and lift tower were removed and incorporated (in part) into the entrance road of the Mildura Marina where they form a distinctive landmark as they have been painted a vivid red colour.

Figure 4.21 The four steel Warren trusses of the former Mildura Bridge after dismantling in 1986

Figure 4.22 The lift tower and two heavily modified truss spans instated on a fixed span concrete bridge at the Mildura Marina (Source: GHD)

Table 4-5 Vertical lift span type 5 – "Swan Hill"

SWAN HILL type lift span bridges	Built	Status	Opening span length
Swan Hill Bridge over the Murray River	1896	Extant	18.4 m
Dunmore Bridge over the Paterson River	1899	Extant	16.7 m
Tooleybuc Bridge over the Murray River	1925	Extant	17.8 m
Mildura Bridge, Murray River	1927	Relocated 1992	17.8 m
Abbotsford Bridge over the Murray River	1928	Extant	19.8 m

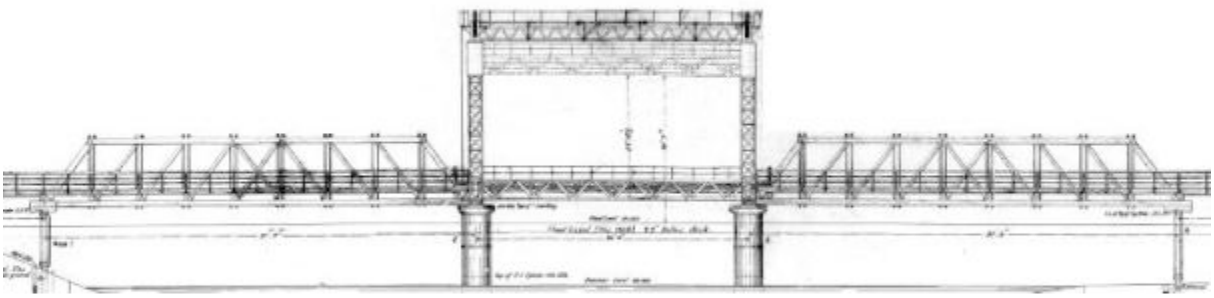

Figure 4.23 Swan Hill Bridge Elevation – 1896 (Source: Allan)

The first generation of vertical lift bridges built in NSW concludes with the design of Abbotsford Bridge completed in 1928 by Percy Allan. This design was informed by the Swan Hill Bridge and the main improvements were the high utilisation of mild steel, the introduction of gusset plates at connections and realignment of tower bracing girders with the towers.

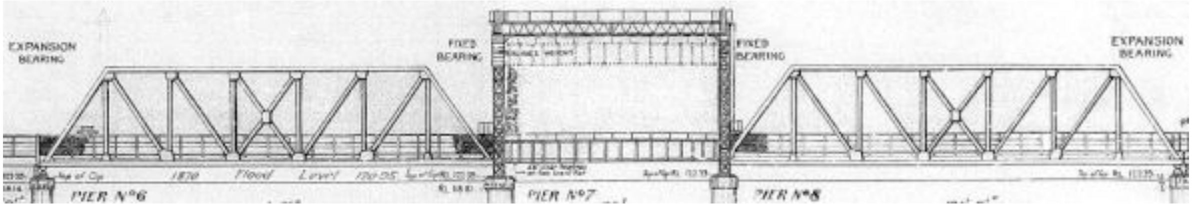

Figure 4.24 Abbotsford Bridge Elevation – 1928

Hinton Bridge was completed in 1901 to a design by E. M. De Burgh which oriented the sheaves back in the longitudinal direction (Figure 4.26). The design also linked the sheaves at either end of the span with wire ropes as opposed to shafts thus effectively reducing the amount of friction in the system. In 1895 De Burgh first trialled this enhanced mechanical arrangement when improving the operational performance of Brewarrina Bridge. Hinton Bridge marked the first opportunity to apply on a new structure. This arrangement was adopted for another three bridges designed by E. M. De Burgh, with each having slight improvements including the implementation of extra ropes into the system, improving aesthetics of transverse tower braces and adding road gates. These bridges include the Murwillumbah Bridge over the Tweed River built in 1901, the Cobram Bridge over the Murray River built in 1902 and the Barham-Koondrook Bridge also over the Murray River built in 1905. Collectively these four bridges form the "Hinton Type" (Table 4-6) as the sixth subset of vertical lift bridges.

Figure 4.25 Murwillumbah Bridge with lift span and four Allan truss spans in 1947, replaced 1968 (Source: RMS photographic archives)

Table 4-6 Vertical lift span type 6 – "Hinton"

HINTON type lift span bridges	Built	Status	Opening span length
Hinton Bridge over the Paterson River	1901	Extant	16.7 m
Murwillumbah Bridge over the Tweed River	1901	Replaced 1968	16.7 m
Cobram Bridge over the Murray River	1902	Extant	15.0 m
Barham Bridge over the Murray River	1905	Extant	17.7 m

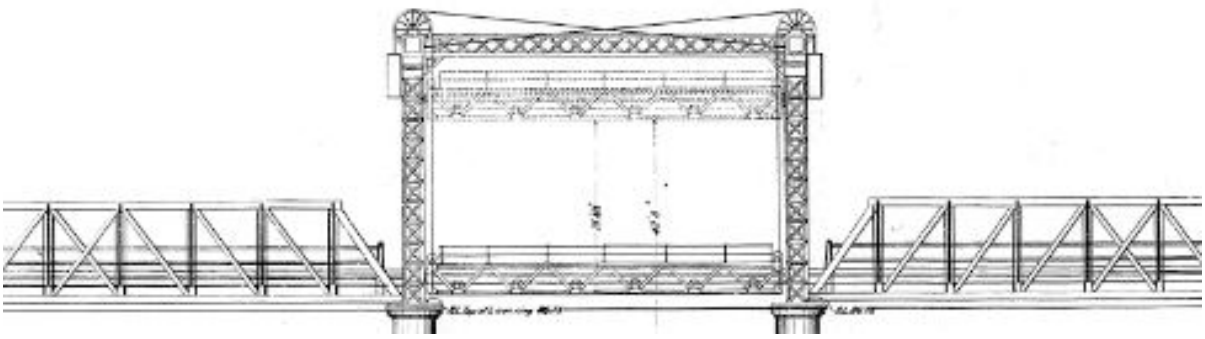

Figure 4.26 Hinton Bridge Elevation – 1901

4.4 North American influences

The first generation of vertical lift bridges were characterised by their small size and application to mainly canals or small inland rivers. This design was sufficient in most respects to European and inland Australian regions, however in North America a need arose to provide movable bridges over larger rivers. This led into the next notable evolution in vertical lift bridge designs and it was achieved by the American borne engineer Squire Whipple who designed his first vertical lift bridge in 1873.

The design was for the Erie Canal Bridge in Utica and although the span design and lifting mechanism were different to that of the preceding R. J. Hood designs, it is unknown if they informed S. Whipple's work. There is some likelihood that S. Whipple was aware of these previous designs, as the patent specifically mentions that he is making no claim on "the original invention of the lift draw-bridge in general" (Whipple, 1873). The designs of S. Whipple continued to progress in America, with a number of bridges successfully designed and constructed.

The development of vertical bridges continued in America with a design prepared by Dr. J. A. L. Waddell. The first design was for a vertical lift bridge over the Chicago River and it was opened in late 1893 (Griggs, 2006). This bridge became the precedent for a number of large span vertical lift bridges, though further improvements continued to be developed in relation to span designs and lifting mechanism arrangements. The striking features of the design are the large towers that have sufficient inherent stiffness to prevent encroach on the span, also the movable span is a truss and mechanical components consist of heavy machinery and motorised components not commonly used in vertical lift bridges. These designs led to the Waddell Type Bridges that were widely adopted in NSW. Figure 4.27 shows a Waddell Bridge built in 1913; it provides a clear comparison to the NSW Ryde Bridge built in 1935.

Figure 4.27 Rail bridge over the Williamette River at Salem, Oregon (Source: Gerald W. Williams Collection, Oregon State University Archives, Corvallis Oregon)

Concurrent with the design of large scale movable bridges was the improvement of vertical lift bridges over small rivers and canals. Waddell's firm designed a number of relatively small vertical lift bridges that used steel plate posts for vertical components and plate web girders as the movable span (Waddell, 1916). This design was adopted for the St. John and Quebec Railway Bridge over the Oromocto River in New Brunswick. It is likely that such designs influenced the second generation vertical lift bridges of NSW, such as Gonns Crossing, this is made evident when comparing the two bridges (Figure 4.28).

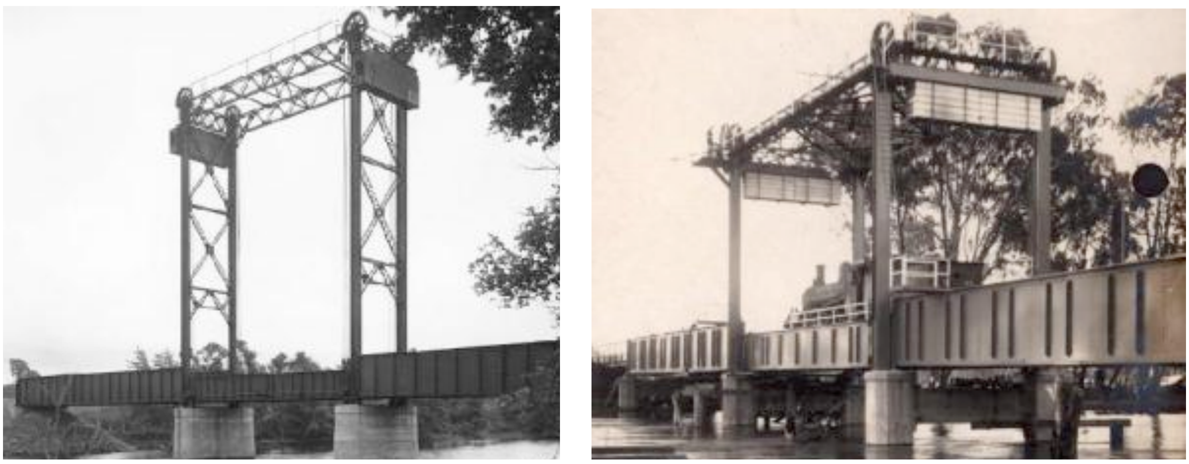

Figure 4.28 St. John and Quebec railway bridge over the Oromocto River in New Brunswick& Gonn Crossing over the Murray River

4.5 Second generation vertical lift span bridges in NSW

The second generation of NSW vertical lift span bridges is defined by a close replication of bridge types widely used in North America. NSW's design input is much less apparent from this time onwards. The next generation commenced with the design of the Robinvale Bridge over the Murray River built in 1925. This design was of steel construction with the most striking feature being the adoption of slender steel columns for the tower components. Further modifications were made to the counterweights with two larger weights being implemented instead of four smaller weights at each corner. This style was applied with very little change to another four vertical lift bridges including Gonns Crossing over the Murray River built in 1926 (Figure 4.32), the Mororo Bridge over the Clarence River built in 1935, the Boyds Bay Bridge over Terranora Creek built in 1937 and the Nyah Bridge over the Murray River built in 1941. Collectively these five bridges form the "Robinvale Type" (Table 4-7) as the seventh subset of vertical lift bridges.

Figure 4.29 View of Robinvale Bridge in 2006 just prior to replacement (Source: RMS photographic archives)

Figure 4.30 Robinvale Bridge lift tower with counterweights removed, established in a park near former bridge crossing

Table 4-7 Vertical lift span type 7 – "Robinvale"

ROBINVALE type lift span bridges	Built	Status	Opening span length
Robinvale Bridge over the Murray River	1925	Replaced 2006	16.7 m
Gonn Crossing Bridge, Murray River	1926	Extant	18.8 m
Mororo Bridge over the Clarence River	1935	Extant	17.7 m
Boyds Bay Bridge over Terranora Creek	1937	Replaced 1985	13.7 m
Nyah Bridge over the Murray River	1941	Extant	18.6 m

Figure 4.31 View of Boyds Bay Bridge in 1985 just prior to replacement (Source: RMS photographic archives)

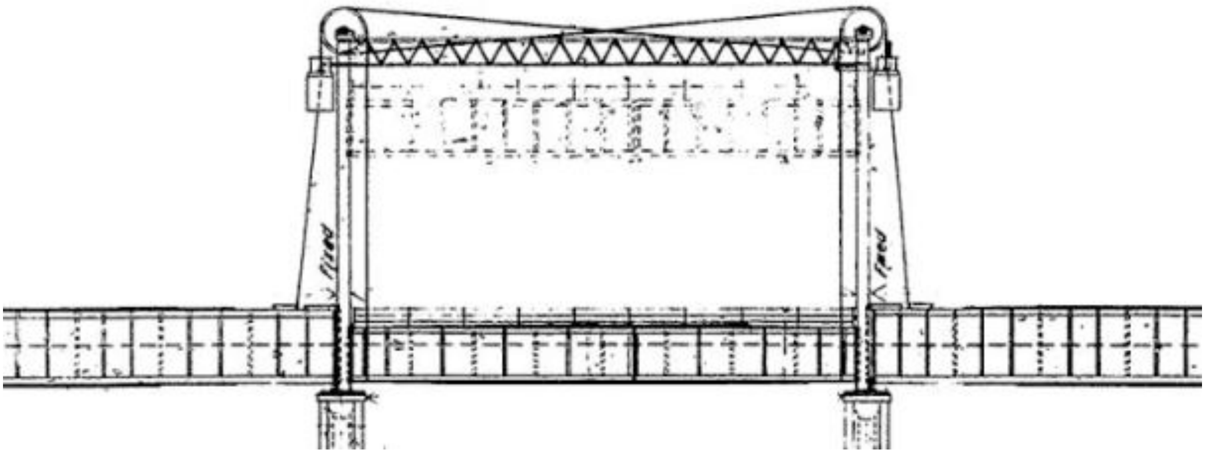

Figure 4.32 Gonns Crossing Bridge 1926

Ryde Bridge was completed in 1935 and adopted the American Waddell type vertical lift span bridge design which had been first built in 1893. The bridge is a larger than previous vertical lift span bridges built in NSW and the components consist of a truss lift span, independent towers and a machinery house. Operation for the bridge was provided for the first time by electrical motors with a backup petrol pony motor installed in case power outages were experienced. This design was typically adopted when a larger span with greater waterway clearance was required. Another four bridges of this type were completed including Martin Bridge built in 1940, Hexham Bridge built in 1952 (Figure 4.33), Batemans Bay Bridge built in 1956, Wardell Bridge built in 1964 and Harwood Bridge built in 1966. These five bridges collectively form the "Ryde Type" (Table 4-8) as the eighth subset of vertical lift span bridges.

Table 4-8 Vertical lift span type 6 – "Ryde"

RYDE type lift span bridges	Built	Status	Opening span length
Ryde Bridge over the Parramatta River	1935	Extant	34.7 m
Martin Bridge over the Manning River	1940	Extant	19.2 m
Hexham Bridge over the Hunter River	1952	Extant	37.9 m
Batemans Bay Bridge over the Clyde River	1956	Extant	28.7 m
Wardell Bridge over the Richmond River	1964	Extant	25.4 m
Harwood Bridge over the Clarence River	1966	Extant	37.8 m

In addition two steel truss bridges were designed so that conversion to a Ryde type bridge was possible if required. These were Iron Cove Bridge at Drummoyne and Karuah Bridge on the Pacific Highway at Karuah. The designs reveal that the central piers were reinforced to carry the extra weight of the towers and the deck joints on the adjacent span made readily removable to facilitate opening.

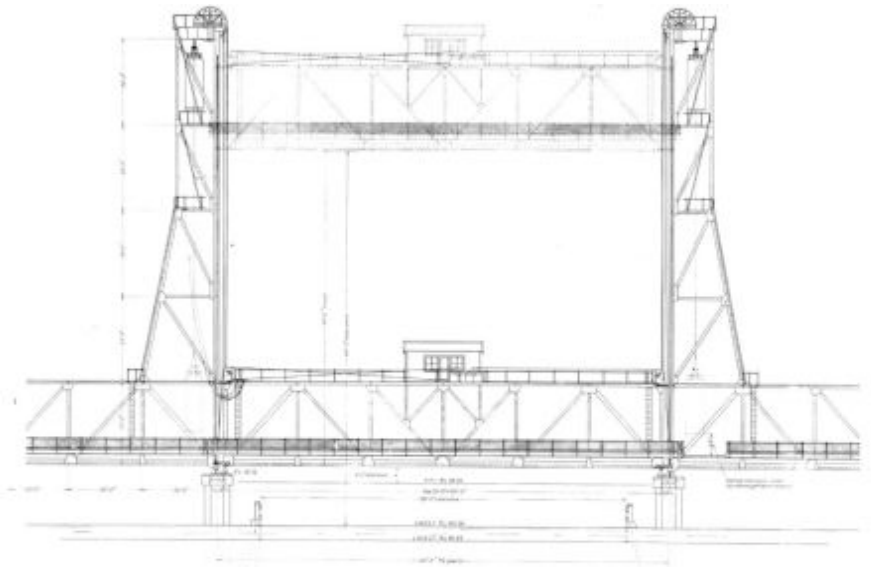

Figure 4.33 Hexham Bridge 1952

Martin Bridge over the Manning River (Figure 4.34) is an interesting modification of the Ryde Type Bridge. The mechanical components of the vertical lift span are similar to those other bridges of the same subset; however the movable span, tower and sheave arrangements have been altered. The movable span consists of a plate web girder instead of the typical truss arrangement, the machinery was mounted below deck level and as such there is no machinery house on the bridge. Vertical columns and subsequent bracing members form a triangular tower to provide support for the counterweight system and guide the span as it is raised. Finally the sheave alignment is of particular interest as they are slightly skewed longitudinally, probably in order to attach to the edge of the movable span and avoid conflict with the road deck. The mechanical components and towers were removed in 1982 leaving only the plate web girder as evidence of the movable span of the bridge.

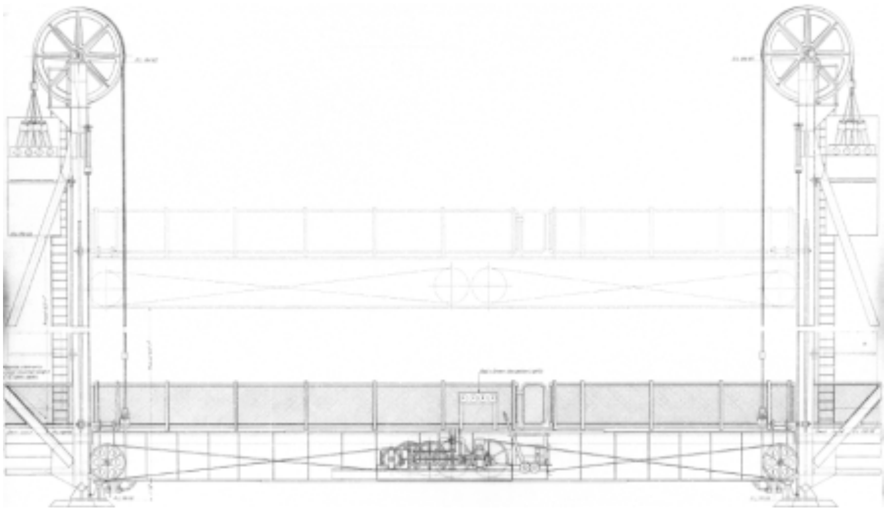

Figure 4.34 Martin Bridge 1940

4.6 Sole table lift bridge in NSW

In NSW the first and only table bridge was constructed over the Darling River at Wentworth in 1969. Due to the large time lapse between the early European bridges and the design adopted for Wentworth, it is difficult to ascertain whether these designs informed the bridge. The European bridges do however provide a reference point and knowledge of their existence may have been sufficient initiate its use in NSW.

The design consists of four hydraulic rams positioned at each corner of the movable span. No other mechanical advantage is provided by means of a counterweighted system and the hydraulics are solely relied upon for the operation of the bridge. As evident by Figure 4.35 when lowered the movable span is almost unidentifiable from deck level.

Figure 4.35 Wentworth Bridge (Source: RMS1969)