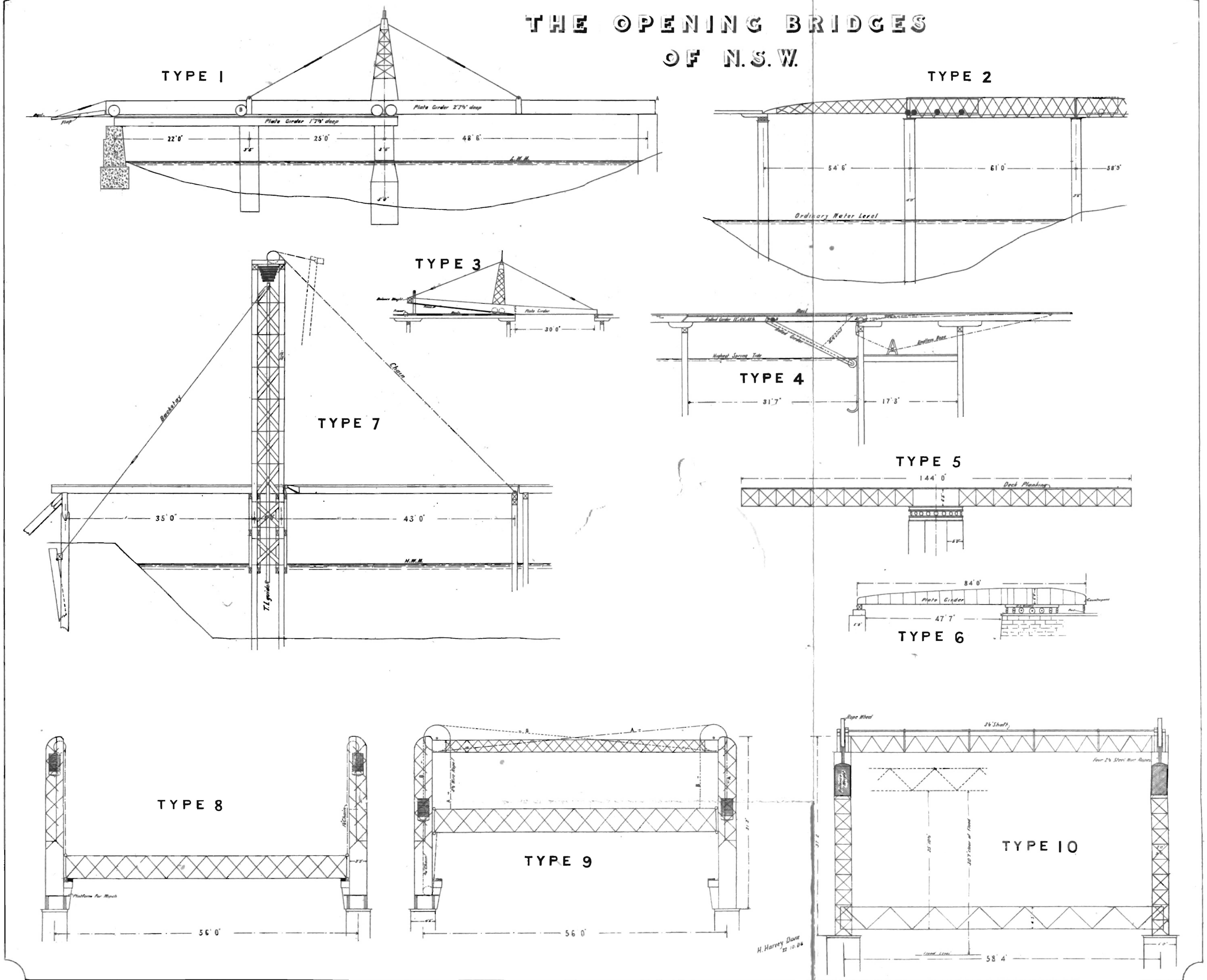
THE OPENING BRIDGES OF N.S.W.



level of the deck. The towers each consist of four 12in. x 12in. timbers, securely braced, and stayed by $1\frac{3}{8}$in. tie rods from the top; they carry a platform on top for inspection of machinery. The feature of the design lies in the arrangement of the balance weights, which are so devised that as the span is raised and the moment of the weight (about 15 tons) of span and chain round the hinge—and consequently the pull on the chain—decreases, the balance weights, which vary in size and weight, are caught one after the other on wrought-iron brackets fixed at calculated intervals on the inside of each tower. The diminishing moment of the weight of span round hinge is thus allowed for by the diminishing moment of balance weights round centre of rope-wheel, and an even balance secured at all stages of the lift. By this means the maximum unbalanced weight to lift or lower is reduced to about 1100 pounds, and one man can open the span to its full extent, or close it, in about ten minutes. These bridges were designed by Mr. J. A. McDonald, late Engineer for Bridges, aud have been working satisfactorily.

The value of one of these spans, with towers, pier, and piles for backstays, is about £1,200 erected.

Division 4.—Lift Bridges.

Three types are shewn, viz., Type 8, used in the earlier lift bridges at Bourke, Balranald, and Brewarrina; Type 9, Bourke Bridge as recently fitted with the De Burgh gear, Balranald and Brewarrina being now in course of alteration in a similar manner; and Type 10, which represents, with various modifications in the arrangement of the machinery, the later bridges at Mulwala, Wentworth, Wilcannia, Tocumwal, and Swan Hill, the last-named only just completed.

Bourke Bridge, over the Darling River, Type 8, the first of the steel lift bridges, was completed in 1883. It consists of four 60 feet lattice girder spans, with timber approach spans, and a steel lift span giving 51 feet 6 inches clear waterway between cylinders. The steel main girders of the lift-span in this and the two subsequent bridges are of the lattice type, 4 feet 3 inches deep over angle irons, 51 feet $10\frac{3}{4}$ inches in long overall, with deck 14 feet wide, carried on steel cross-girders spaced 3 feet 11 inches apart, resting on the bottom flange. At each corner of the span 6-inch wrought-iron rollers, working in recessed cast-iron paths bolted to the towers, serve to guide the span during opening and closing. As originally built, the span was lifted and lowered by a pair of winches, carried on platforms on the downstream side of bridge, each winch giving motion to a pair of sprocket wheels inside the towers, connected by a transverse shaft under the deck and operating a $\frac{5}{8}$-inch chain, one end of which led to the bottom of the balance weights inside the towers, while the other end was connected to the underside of main girders. At the top of each tower was fixed a chain wheel 2 feet 2 inches in diameter, over which passed a $1\frac{1}{4}$-inch chain, connecting the open span with the balance weights.

To open the span, two men, one at each winch, supplied the necessary power, hauling on the bottom of the balance weights, which were drawn down and the span raised, the operation being reversed for closing; the pull in this case being on the bottom of main girders.

Balranald Bridge, over the Murrumbidgee River, is of a similar type to Bourke Bridge, and was erected at about the same time.

Barwon River Bridge, at Brewarrina, opened 1888, was the last of the lift bridges in which chains were used for working the span. It consists of timber approach-spans, with steel lift-span similar in general design to those at Bourke and Balranald, but with various improvements in the towers and machinery, and having a timber deck. In the two previous bridges, difficulty had been experienced owing to the impossibility of getting the two winches to work together, in consequence of which one corner was raised faster than the other and the span tilted and jammed against the towers. To obviate this defect, the chain wheels in Barwon Bridge were cast with a bevel on the side which worked in a bevel pinion keyed to either end of a $2\frac{1}{8}$-inch longitudinal shaft carried from the underside of the bracing girder between towers at the top, thus ensuring the equal lifting of the span at each corner. With the increased power provided in the gearing, two men could lift the span with ease, but since there is frequently only the caretaker available, the use of two winches naturally became inconvenient and tedious, the man having to make short lifts at each in turn, and the bridge is now being fitted with new gearing of the De Burgh type. The height of towers in Barwon Bridge is 30 feet $6\frac{1}{2}$ inches above top of cylinder; centres of main girders, 16 feet; weight of span about 20 tons; and width of deck 14 feet between kerbs.

In 1895 the working of the lift-span in Bourke Bridge had become so unsatisfactory owing to the want of rigidity in the towers, due to the lack of overhead bracing, combined with the tendency of the span to jam, caused by the uneven working of the two winches before referred to, that it became necessary to make an alteration in the lifting arrangements. This was effected by substituting the gearing designed by Mr. E. M. de Burgh, Assistant Engineer for Bridges, as shewn in Type 9, the buckled-plate deck on the lift-span being at the same time replaced by timber stringers with 4-inch planking. The alterations to the gearing were as follows: The towers were connected longitudinally at the top by a pair of lattice girders 2 feet 3 inches deep, braced in the horizontal plane by diagonal rods, forming a stiff connection and counteracting the previous tendency of the tops of the towers to come together during the working of the span. One winch was done away with, and the power of the gearing in the other was increased from 36 to 1 to 117 to 1 by the addition of another wheel and pinion. The four chains connecting the span to the balance weights were replaced by four flexible galvanized crucible steel-wire ropes, each $3\frac{1}{2}$ inches circumference, passing over four new rope wheels 5 feet 10 inches in diameter on a pair of transverse shafts at the top of the towers. The novelty of the design lies in the arrangement of the ropes. Each rope, instead of passing direct from top of main girder, over rope-wheel, to balance weights, as was the case with the chains previously used, is now brought from top of main girder, round one rope-wheel, and over the rope-wheel on the opposite tower, to the opposite balance weight, as shown in diagram. By this means each rope is kept tight by the pull of the balance weight, and, at the same time, all the rope-wheels are caused to move uniformly when worked from a single winch, the span lifting evenly at all four corners. This gearing has proved both speedy and effective, one man being able to raise the span through the full height of its lift in eight minutes, while the motion is smooth and even throughout, and with an entire absence of the jarring and shock essential where chains are used. A contract has been let for the supply of similar gearing for Balranald and Barwon River bridges, the contract cost of ironwork (supply only), including alteration to bracing girders, etc., being £355 for the two bridges; this work is now in hand.

The lift bridge over the Murray River at Mulwala, completed in 1892, was the first bridge in which steel wire ropes were employed instead of chains for lifting. In this bridge, designed by Mr. J. A. McDonald, many improvements were made in the lift-span itself, and also in the towers and machinery. The lift-span is of the type subsequently used in Wentworth, Wilcannia, Tocumwal, and Swan Hill bridges, and described subsequently for the last-named bridge, with the exception that in this case (and in Wentworth Bridge) the deck is 16 feet 6 inches wide between kerbs, instead of 14 feet as in the later bridges. With this exception, and that of some variations in the arrangement of the balance weights and gearing, the lift-spans in all these bridges are similar in design, the leading particulars being summarised in the table at the end of the paper. Swan Hill Bridge, as the latest of the type, only very recently completed, merits perhaps a detailed description.

Swan Hill Bridge, Type 10, is the farthest from its source of the three steel lift bridges over the Murray River, the order being Mulwala, Tocumwal, Swan Hill, all three erected at the joint expense of the two colonies of New South Wales and Victoria: the work was designed and carried out in each case by the Bridges Branch of the Public Works Department of this colony. In this bridge there are two 90-feet timber truss-spans, with timber beam approaches, and a steel lift-span of 58 feet 4 inches centres of piers, giving 50 feet 5 inches clear waterway, and 30 feet 7 inches clear headway above highest known flood level when the span is raised to its full height. The two steel main girders of the lift-span are of the Warren type, 59 feet 8 inches long overall, 4 feet 2 inches deep over angle bars, with booms formed each of two steel angle bars, and steel flange plates 12 inches wide; the web-bracing consists of double channel bars set at an angle of 45°, and stiffened internally with ladder bracing to form struts. Fishbellied steel cross-girders are secured to saddle plates rivetted to the bottom booms at intervals of 8 feet 4 inches, and carry on their upper flanges six 10in. x 6in. ironbark stringers, to which is spiked the tallow-wood planking forming the deck, which is 11 feet wide on the lift span, increasing to 18 feet 3 inches wide between kerbs on the truss spans. A system of bracing is provided between the main girders, connecting the lower flanges of main girders by means of steel bars with union screws at centre and rivetted to gusset plates on booms.

The total weight of span complete is about 34 tons, and this is counterbalanced by four cast-iron balance boxes, filled with lead, connected to the span each by four $2\frac{1}{2}$-inch steel wire ropes, passing over a rope-wheel at the top of tower and spliced, one end round a pin in a forged steel suspension bracket on the top flange of main girder, the other end round the eye of a square suspension rod passing through the balance weight. In the earlier lift bridges the balance weights were designed to work inside the towers, but this has been found unsatisfactory, owing to the friction of the weights on the sides, and in the later bridges they travel on V girders bolted to the towers on the outside, at right-angles to the centre line of bridge. For guiding the span during lifting and lowering, there are two cast-iron guide wheels at each corner, secured to the main girders, and working, in planes at right-angles to each other, on vertical steel rails fixed to the towers.

The principal difference between the design of the lift span for Swan Hill Bridge and that of the other four lift bridges of the same class, lies in the arrangement of the shafting and overhead bracing, as follows: In Mulwala and Wentworth bridges, the first of the class erected, there are a pair of overhead transverse bracing girders, and a pair of overhead longitudinal bracing girders between the towers, the latter carrying a platform over the centre of the span, on which rests the winch. Under the winch, and worked by it, there is a longitudinal shaft running along tbe centre line of bridge, and working, by means of bevel gearing, a transverse shaft between each pair of towers, on each end of which is keyed a rope-wheel.

Wilcannia and Tocumwal bridges have a different arrangement; the winch, though carried on a central overhead platform as before, gives motion in these bridges to a central *t ansverse* shaft, which in turn actuates a longitudinal shaft on each side of the bridge, the rope-wheels being keyed to each end of the longitudinal shafts. Roughly speaking, the one arrangement of shafting is an H, the other an ⌶, with the winch in the centre in each case. Some difficulty was experienced with both these arrangements, owing to some deflection in the longitudinal bracing girders, which gave rise to torsion in the longitudinal shafts, and in Swan Hill Bridge a different system has been adopted, the overhead platform being done away with and the span operated from the level of the deck.

The towers, which are 3 feet square, 34 feet 2 inches high, above top of cylinder, are formed each of four L irons, running down 6 feet into the cylinder, and bolted to wrought-iron diaphragms rivetted to the shell plates of cylinder. They are braced with horizontal T irons and diagonal bars, and stiffened at the top by transverse and longitudinal lattice bracing girders, 3 feet deep, the latter connected at the centre by a light lattice girder, thus forming two bays of overhead bracing, in each of which are a pair of diagonal rods connecting the centre of longitudinal girders with tops of towers; this forms a stiff overhead connection.

To operate the span there is a vertical shaft running in bearings on one of the towers and worked from the platform at level of deck; this gives motion to an overhead longitudinal shaft carrying a pinion on each end, working in teeth cast on the inside rim of a grooved rope-wheel 5 feet 4½ inches in diameter, and at the same time actuates a transverse shaft over the towers connected to a longitudinal shaft on the opposite side of the bridge. All four rope-wheels are thus caused to work together, and as the longitudinal girders have no longer to support the weight of a platform at the centre, the deflection, and consequently the torsion, in the shafts is minimised. With the new arrangement of gearing, one man can open the span in five and a-half minutes through the full height of the lift, which is 25 feet in this case, as against 21 feet in the previous bridges.

The contract cost for the lift-span in Swan Hill Bridge, with towers and machinery complete (including an item of £250 for carriage of metal work), was £2,600. This represents a considerable saving compared with the cost of previous bridges of the same class, and at the same time provides a more efficient structure and one which has the advantage of greater convenience in operation, inasmuch as the lifting machinery is worked from the level of the deck. The bridge was designed by Mr. Percy Allan, under Mr. R. R. P. Hickson, M. Inst. C.E., and has been erected under Mr. C. W. Darley, Engineer-in-Chief for Public Works, Mr. D. W. Armstrong acting as Resident Engineer in charge of the work.

Summarising the results obtained then with the various opening bridges erected up to the present time, it may be said that:—

1. Of the four types of traversing spans used, only one has given successful results. None of these bridges, however, are of recent date, and it is not likely that this style of opening span will be repeated in the future.

2. No large swing bridge of the proportions so common in America has yet been found necessary, but swing spans have been built giving openings up to about 54 feet wide in the clear. These are almost all of the deck type, and satisfactorily meet the requirements in most cases.

3. The timber hinged leaf type has proved economical and reasonably efficient where the water traffic to be provided for is light in character, and includes masted vessels of small size. A bridge of this class can be erected where the cost of any of the other types would be prohibitive.

4. The best results obtained have been with the later steel lift bridges over the rivers of the interior, of which Bourke Bridge, since it was fitted with the De Burgh gear, and Swan Hill Bridge, which has the greatest lift of any, furnish good examples of different methods of working the same span. It would be difficult to improve upon the design of these bridges, or to provide a class of structure equally as well adapted to requirements at anything approaching the same cost.

In conclusion, the writer wishes to express his thanks to Mr. C. W. Darley, Engineer-in-Chief for Public Works, for permission to use the plans of the Department in connection with this Paper, and to the various gentlemen who have been so kind as to supply him with information concerning the matter treated of.

Summary of Particulars of Opening Spans.

Bridge.	Type.		Date of Complet'n.	Width of Deck.		Minimum Clear Waterway through Opening Span.		Lift. Total.	Lift. Cl'ar of Flood.	Men to Open.	Time to Open.
				FT.	IN.	FT.	IN.	FT. IN.	FT. IN.		MIN.
*Dunmore Bridge, Paterson R....	Traversing	Type 1	1864	14	4	45	0	—	—	—	—
Lansdowne R., at Coopernook...	,,	,,	1884	12	0	45	0	—	—	2	30
Erina Creek, at Gosford ...	,,	,,	1885	12	0	44	3	—	—	2	30
Wilson's Creek, at Lismore ...	,,	Type 2	1884	14	0	49	4	—	—	—	—
Cook's River, at Sewage Farm...	,,	Type 3	1887	4	$8\frac{1}{2}$	28	0	—	—	2	5
Lake Macquarie, at Swansea ...	,,	Type 4	1871	13	0	30	0	—	—	—	—
Darling Harbour, Sydney ...	Lattice swing	—	1857	16	10	51' 6" and 35' 6"		—	—	2	2
Glebe Island, Sydney	Plate swing	—	1862	14	0	34	0	—	—	2	3
Hay Bridge, Murrumbidgee R...	Lattice swing	Type 5	1873	15	0	Two 49' 6" each		—	—	1	4
Parramatta R., near Sydney ...	,,	,,	1881	24	2	Two 54' 1" each		—	—	1	3
Lane Cove R. ,, ,, ..	Plate swing	Type 6	1885	24	3	One 47' 7"		—	—	1	6
Belmore R., at Gladstone ...	Hinged leaf	Type 7	1891	10	6	40	0	—	—	1	10
Camden Haven R.	,,	,,	1891	10	6	40	0	—	—	1	10
Shea's Creek Canal	,,	,,	1892	10	6	40	0	—	—	1	10
Kinchela Creek...	,,	,,	1893	10	6	40	0	—	—	1	10
Darling R., at Bourke	Steel lift	Types 8 & 9	1883	14	0	49	7	18·0		1	8
†Murrumbidgee R., at Balranald	,,	,,	1883	14	0	49	3	—	—	—	—
†Barwon R., at Brewarrina ...	,,	Type 9	1888	14	0	47	9	—	—	—	—
Murray R., at Mulwala ...	,,	Type 10	1892	16	6	46	$3\frac{1}{8}$	20·0	23·4	1	$5\frac{1}{2}$
Darling R., at Wentworth ...	,,	,,	1893	16	6	46	$3\frac{1}{8}$	20·0	24·9	1	$5\frac{1}{2}$
,, ,, Wilcannia ...	,,	,,	1896	14	0	50	5	21·0	25·0	1	$5\frac{1}{2}$
Murray R., at Tocumwal ...	,,	,,	1895	14	0	50	5	21·0	26·0	1	$5\frac{1}{2}$
,, Swan Hill ...	,,	,,	1896	14	0	50	5	25·0	30·7	1	$5\frac{1}{2}$
North Creek	Timber lift	—	—	10	0	26	0	20·0	—	—	—

* To be replaced in 1897 by a steel lift bridge.

† Now being fitted with the de Burgh gear.