Load Transfer Sequencing for Maintenance of Lift Span Bridges

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ABSTRACT

The Nyah Lift Span Bridge and the Gonn Crossing Lift Span Bridge are two vertical lift span structures in regional NSW, maintained and operated by Roads and Maritime Services (RMS). They represent two of the remaining operational lifting bridges from the early-mid 20th Century and act as critical transport links between townships along the Murray River. BG&E has completed the temporary works design and construction methodology for remediation of the two bridges. The works included the design of a load transfer mechanism to support 40 tonne counterweights so that the aged cables linking the counterweights to the lift span could be replaced. Works were designed to allow limited traffic on the structure to reduce impact on the local community, and to minimise the structural / aesthetic impact on the historic structures. Due to geometric constraints the same methodology was not applicable to both bridges and required innovative thinking to reduce obstruction of the carriageway while maintaining existing load paths where possible. This paper will discuss the load transfer sequencing used for the two bridges.

INTRODUCTION

Lift span bridges – with a history dating back at least as far as the bascule type draw bridges of the middle ages – typically have a central main span that is capable of moving out of the way in some manner to allow the passage of ships too high to pass beneath the structure. They have the benefit of not requiring large built up embankments associated with high level crossings, and so are often used in low lying regions where high embankments may prove costly. In total, there have been sixty-six movable span bridges constructed in New South Wales [1]. Forty of these bridges have since been demolished, such that RMS currently has twenty-six movable span structures under their management, with fourteen of these still operational. Seventeen of the movable span bridges managed by RMS are categorised as vertical lift span type [2].

Vertical lift span structures are easily identified by having tall column structures either side of the central lift span, providing support for the lifting pulley system and guiding the moving span vertically. The weight of lift span is balanced by two counterweights at either end of the span to reduce the effort required to raise the span, such that a closed mechanical system is achieved and operation of the lifting mechanism can be completed by hand. In earlier designs the columns were independent from each other, which led to jamming as the columns deflected under load [3]. The winches used to lift the span were also independent, making it difficult to lift uniformly and increasing the likelihood of jamming. Later designs saw these columns braced off each other to improve restraint and limit deflections (See Figure 1). More complex lifting mechanisms were also employed to ensure an even lift was carried out. Both the Gonn Crossing and Nyah bridges have braced column structures. Their lifting mechanisms can be operated either by hand or using a motorised assist to increase the efficiency and limit the impact on local residents. The counterweights of the two structures are connected to the lift span by steel wire cables.

RMS in South West Region in NSW is responsible for the operation and maintenance of seven operating lift span bridges, six over the Murray River at Barham-Koondrook, Gonn Crossing-Murrabit, Swan Hill, Nyah, Tooleybuc, Abbotsford, and one over the Darling River at Wentworth. The ongoing challenge with these structures is maintaining a level of service that ensures safe passage of road vehicle traffic and river boating traffic, which always have conflicting needs. The Constitution of Australia also has a requirement that a navigable waterway must be maintained, so these opening bridges will remain in service, and there are no public fees charged for this service. Murray River levels are generally uncontrolled and unpredictable, which impacts on the ability to predict the frequency of openings required for these lift span bridges, and the level of planned maintenance. Some bridges are opened several times a day, while others are opened only several times a month, depending on river levels.

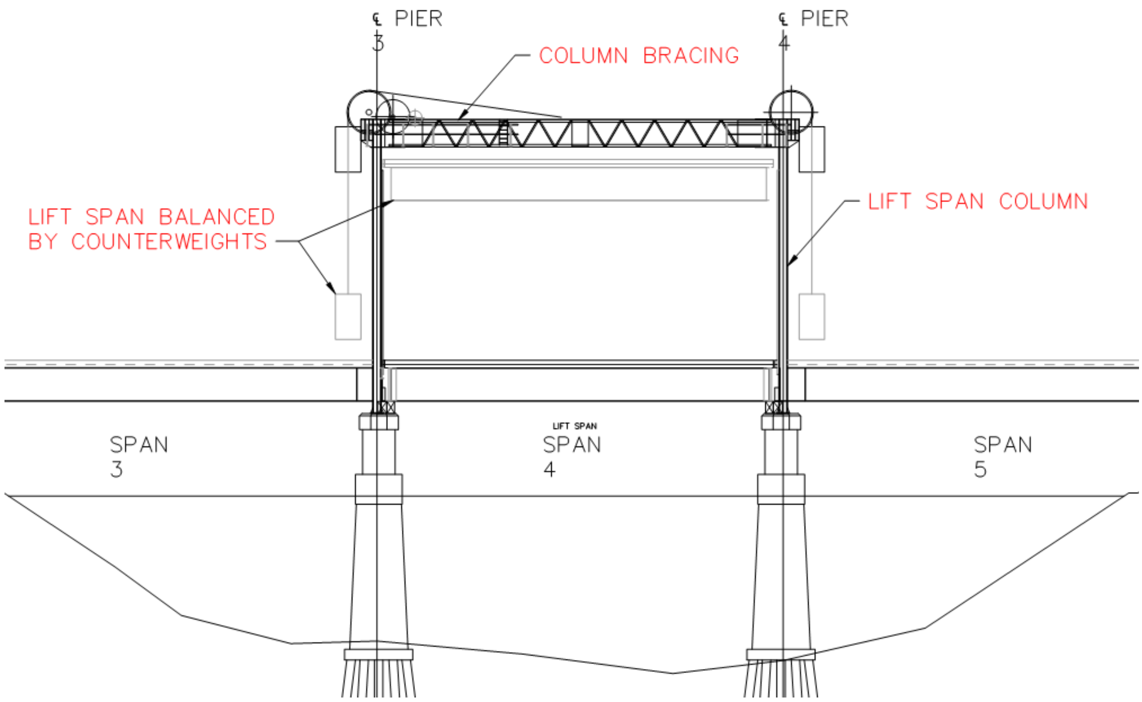

Figure 1 - Typical vertical lift span components and operation

NYAH LIFT SPAN BRIDGE

The Nyah lift span bridge was officially opened in July 1941, having been opened to traffic from May of the same year [4]. It connects the two towns of Nyah on the VIC side of the border and Koraleigh to the north in NSW along Speewa Road. The bridge has a total length of 342ft (104m), with a 62ft (19m) central lift span and three approach spans either side [5]. The bridge is a mix of structural steel and concrete, and is two lanes wide. The central lift span can be raised to achieve 34ft (10m) clearance to the high flood level, and was considered one of the most modern structures over the Murray River at the time of its construction [4]. The bridge is considered socially significant due to it being a major artery across the Murray.

Steel wire cables provide a link over the pulley system between the lift span and the counterweights, with three cables supporting each corner of the lift span. Two of these cables are connected over the pulley system to the counterweight at the same end of the span. One cable from each corner wraps around the pulley directly above and continues over the pulley at the opposite end, connecting to the opposite counterweight. This system ensures that both counterweights and ends of the lift span move in synchronisation to reduce the likelihood of jamming. The steel wire cables were showing signs of degradation and required replacement.

In order to replace the degraded cables, RMS required a system to support the counterweights during the process. The system needed to be able to relieve the tension in existing steel cables to allow the safe removal and also installation of the new cables. Due to access and cost constraints large cranes were ruled out, and BG&E were brought on to design the support system. The contract stipulated that the bridge was to remain open during the process with only limited closures, which further restricted the available support proposals.

Several support techniques were investigated, including static supports to the counterweights and jacking up the bridge to relieve the tension in the cables. This would have required ramps at either side of the lift span to allow traffic. It also required fairly extensive support structures that limited the access width for vehicles. Having large temporary columns supporting the counterweights was also seen as a risk, as they could easily suffer impact from a passing vehicle. Another process investigated was to have the two counterweights connected directly to each other as shown in Figure 2, however a practical method of securing the two counterweights could not be guaranteed and the existing components were found insufficient for the increased lateral loading this particular support method would have applied.

The design intent of the chosen method, shown in Figure 3, was to use the existing structure where possible. The counterweights were lifted at each end by stressing strands draped over an available width in the existing pulley system. This maintained the existing load paths that the original structure was designed for. A bracket was welded to the side of the column, near deck level, to act as the anchorage point for the stressing strand. Hollow core jacks could then be attached to the base of the welded bracket and used to lift the counterweights. A stool was designed to be inserted around each jack after the jacking process so that the counterweights were not held under hydraulic pressure which would have been a significant safety risk. This also protected the jacks from vandalism during the replacement procedure. Due to the eccentric loading, small additional loads were applied to the column. The capacity of the column was checked for these additional loads and found to be sufficient.

The existing counterweight support brackets were investigated and it was deemed impractical and unsafe to utilise them for the temporary support. A custom cradle was designed for the counterweight to improve the safety of the process and provide solid support points for the stressing strands. In order to maintain the balance of the pulley system, when the cradles were attached to the counterweights it was anticipated that additional weight needed to be added to the lift span. The planned approach was to place plastic barriers on the lift span prior to installing the cradles and filing them with water after the installation to balance the weight and allow seamless use of the lifting mechanism. This would have reduced the bridge width, however one lane could remain open allowing access and it was the cheapest solution for the client. The barriers would also help to improve the safety of the works being undertaken. On site it was found that this was not required, and that the additional weight of the cradles did not impact the use of the lifting mechanism.

The construction methodology devised also allowed a vast majority of the technical work to be completed at bridge deck level. This limited working at height concerns for the works. Lastly the design allowed for the bridge to remain open to car traffic throughout the remediation works, which was deemed critical for the project. Site works were completed during bridge closures between 7am and 5pm on weekdays from Monday 13 April to Friday 24 April 2015, with two half-hour opening blocks each day for school traffic between 7.45am and 8.15am and 3.45pm and 4.15pm. Works were valued at $700,000.

On completion of steel wire rope replacements, the old 35mm 6 x 19 IWRC Galvanised 1770 Grade cables were destructive tested and broke at between 674kN and 799kN. The minimum breaking force required for this size is 716kN according to AS3569. It is expected that with the loss of the protective coating there would be further reduction in capacity at an accelerating rate.

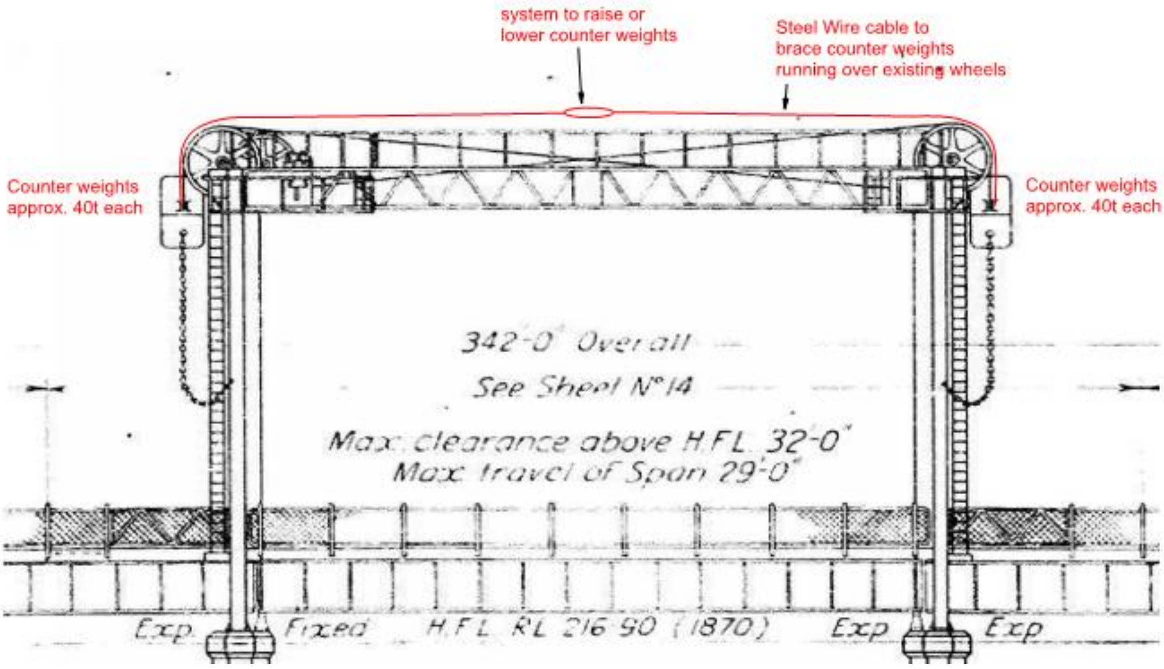

Figure 2 - Preliminary concept support design for the Nyah lift span cable replacement

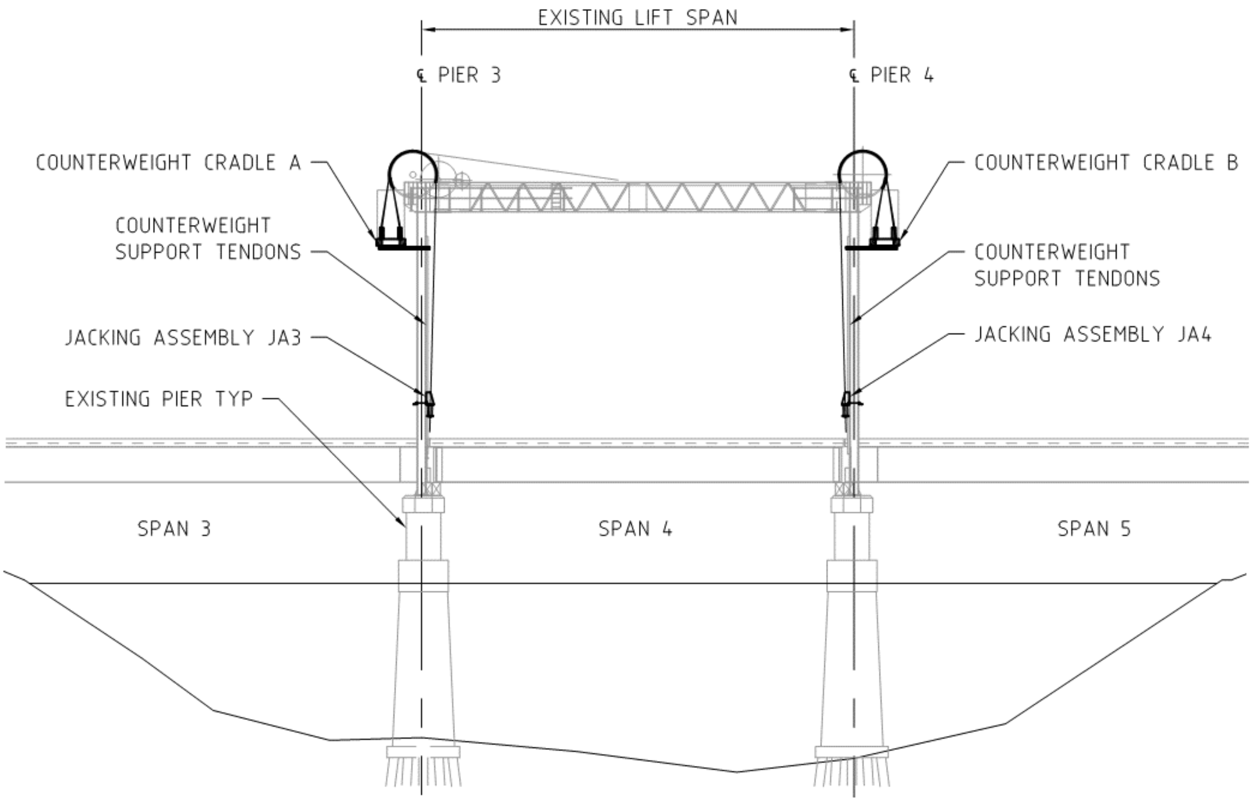

Figure 3 - Support system design used for the Nyah Bridge steel cable replacement procedure

Figure 4 - Bracket and jacking assembly welded to the existing column on the Nyah Lift span bridge

Figure 5 –Support cradle attached to raised counterweight

GONN CROSSING-MURRABIT LIFT SPAN BRIDGE

Gonn Crossing Bridge is located on Murrabit Road and carries traffic over the Murray River between the township Murrabit to the south in VIC and the locality of Gonn Crossing to the north in NSW. The bridge was opened on July 1, 1926, and was the first all-steel construction lift span across the Murray between Victoria and New South Wales. The bridge was originally designed to carry both road and rail traffic, and includes a central span (17.7m, 58ft) able to be lifted by a winch along with six additional approach spans totalling approximately 103m in length [6]. The bridge lies on a north/south axis and consists of 7 structural steel spans with timber decks. The bridge is supported on concrete pile caps founded on concrete piles. The central lift span is balanced by means of a counterweight system to facilitate lifting by manual means. Steel cables provide the link over a pulley system between the lift span and two concrete counterweights, one at either end of the lift span [7]. Similar to the Nyah Bridge, the steel cables connecting the lift span to the counterweights had deteriorated over time and required replacement.

The original intent was to use a similar process to the Nyah lift span cable replacement. This system had been proven to be effective and would incorporate re-use of the existing components, reducing costs and waste. Unfortunately the geometry of the Gonn Crossing Bridge was too dissimilar to allow the use of the existing system and components, and so a new methodology needed to be devised. Continued access by local residences was once again a requirement of the design.

The design methodology devised aimed to simplify the procedure used on the Nyah lift-span bridge and use proprietary products where possible. In this instance, the bridge geometry could readily accommodate direct support of the counterweights on

Megashor 1000kN support struts, braced to the existing columns. The struts were each raised by a hydraulic jack to lift the counterweights and remove tension in the steel cables in order to limit manual labour and improve efficiency. The lift needed to be carried out in synchronisation between all four points due to the articulation of the wire cables. The support struts were supported on top of the approach span girders, applying additional load to this structure that would need to act in combination with existing road traffic. Having originally been designed for rail traffic, the affected components were found to be sufficient for this application.

The construction methodology devised allowed a vast majority of the technical remediation work to be completed at bridge deck level. This limited working at height concerns for the works. Lastly, the design allowed for the bridge to remain open to vehicular traffic throughout the majority of the remediation works as per the project requirements.

Site works were completed during two days of bridge closures from the 30 November to 1 December 2015 from 9AM to 3:30PM with an opening time of 12-1PM, and for 3 weeks from 4 January to 5 February 2016 from 8am to 5pm. Works were valued at $850,000.

Figure 6 - Photo showing the counterweight support design implemented on the Gonn Crossing Bridge

Figure 7 - Historic plaque installed at the Gonn Crossing Bridge

Figure 8 - Jacking stool installed underneath the Megashor struts used to lift the counterweight

Figure 9 – Cross section through the old steel wire rope removed from the Gonn Crossing Bridge

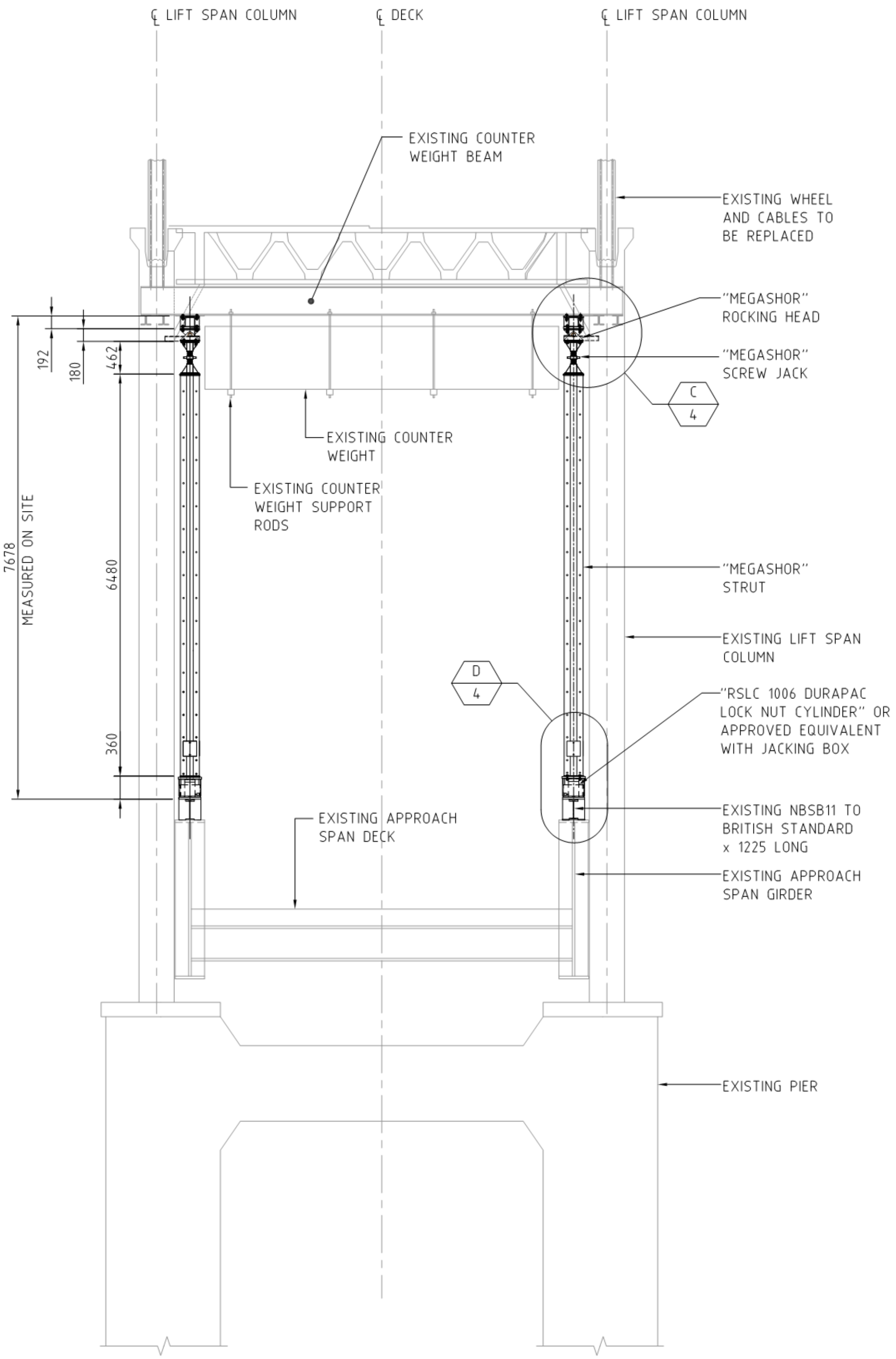

Figure 10 - Support system design used for the Gonn Crossing Bridge steel cable replacement procedure

CONCLUSION

BG&E have devised two separate methods to support the counterweights of historic lift span structures. Each method responded to the specific structural and geometric constraints offered. Both methods were successful in allowing for the continued use of the crossings by the public, other than during critical tasks, to minimise the impact on local communities reliant on the crossings for their daily tasks. Effective Safety in Design processes were used to establish safe work practices and methodologies. Similar methods could be used for the other vertical lift span structures maintained by RMS and other authorities for similar maintenance tasks.

DISCLAIMER

The opinions expressed in this paper are those of the authors and do not necessarily reflect the policies and practices of NSW Roads and Maritime Services.

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