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DR. J. A. L. WADDELL'S CONTRIBUTIONS TO VERTICAL LIFT BRIDGE DESIGN

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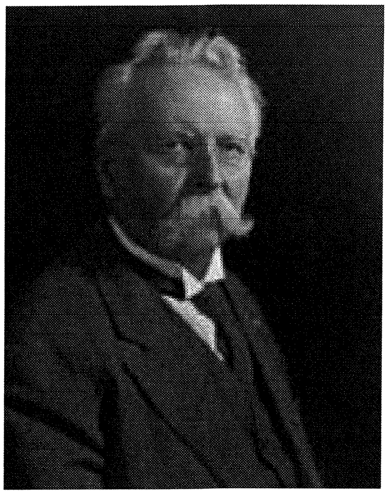
"The absolute ignorance of students at engineering schools, of young engineers, and, it must be confessed, also of many old members of the engineering profession, concerning the history of civil engineering and the names of the prominent engineers of past and present times, is simply astounding!"
– J. A. L. Waddell, 1903[1]

"The Halsted Street Lift Bridge describes one of the most unique structures in America, and, while it is improbable that another bridge of that type will ever be built, owing to the later development of the bascule bridge, many of the devices employed are valuable and structures will be of especial interest to the student of movable bridges" – John Lyle Harrington, 1905[2]



Dr. J. A. L. Waddell – Father of the modern Vertical Lift Bridge (Collection of Hardesty & Hanover, LLP, New York: Underwood and Underwood Studios)

Dr. John Alexander Low Waddell is generally considered the father of the modern vertical lift bridge, one of the three primary movable bridge types that are common throughout the United States today. This paper explores Waddell's role in development and implementation of the vertical lift bridge, a type of movable bridge which lifts up to open while its deck remains level.

The evolution of the modern lift span started with the construction of low height lift bridges over inland barge canals, first in Europe and later in the United States. Traffic on canals was primarily low canal boats which were pulled along via tow paths. With no need for sails, these vessels were low to the water and they tended to move quite slowly. The next generation of movable spans had to meet a new design parameter, they needed to allow passage of tall-masted vessels used for ocean and lake transportation. This generation of movable spans tended to be primarily swing spans which pivoted in a horizontal plane about a central pier. The swing span easily accommodated the tall narrow sailing vessels of the mid 1800's but the central pivot pier was a potential obstruction to navigation [3].

In the late 1800's, the United States was undergoing tremendous economic growth and industrialization, which lead to growth in vessel size, and a shift from sail to steam powered vessels. Confronted with the conflicting demands of navigation interests and bridge owners, which included numerous local governments as well as railroads, the federal government stepped in by requiring wider navigation channels at bridges. In the 1890's, Congress authorized the War Department to approve plans for all new bridges over navigable waterways and to seek alteration of any existing bridge that interfered with "reasonably free, easy and unobstructed" navigation. As the War Department first wielded its authority in the early 1890's, they dictated parameters for the design of the Duluth Ship Canal Bridge and later the replacement of the South Halsted Street Bridge in Chicago. Dr. J. A. L. Waddell, already a well-known and able bridge engineer, used these projects to leap into the forefront of vertical lift bridge design Waddell's role in vertical lift bridge development included individual invention and resulting patents; implementation of his inventions in numerous vertical lift bridges built throughout the United States and in other parts of the world; and inspiration to an entire generation of bridge designers and successor engineering firms claiming Waddell as their founder [4]. Dr. Waddell promoted the basic principals of the medium to high lift vertical lift span for specific project applications, and is responsible for the design of the first modern vertical lift span built at South Halsted Street in Chicago. The basic design of the South Halsted Street Bridge and other modern vertical lift spans involves two towers with sheaves at the top over which counterweight ropes pass to lift the span. This arrangement allowed for a wide channel and a relatively high height lift. Variations on the broad basic design include features for operating and balancing the span. At least four long-span, high-lift, vertical lift bridges were designed in Europe in the mid 1800's but none were built and thus Waddell was the first to have a bridge built based on this type of design[5]. Vertical lift bridges based on the basic principals of Waddell's early designs represent the third most common movable bridge type in the United States today behind the bascule and swing span and represent the preferred choice for long span movable bridges. While political conditions and mechanical refinements needed in the initial design hindered rapid widespread use of vertical lift spans, perseverance and assembly of an appropriate engineering team lead to the rapid acceptance of the vertical lift bridge in the early 1900's.

Biographical Information

John Alexander Low Waddell was born in Port Hope Ontario in 1854. His father was a high official in the local government who instilled in Waddell a desire to study at an early age. After a trip to China and a short time at a business college, Waddell was ready for engineering. He chose to come to the United States to study at one of the best engineering schools, Rensselaer Polytechnic Institute where he earned his degree in 1875. As with most young engineers, Dr. Waddell sought to gain varied experience in the field, develop his professional knowledge and earn a living. Some of his earlier experience was not particularly interesting, but perhaps this is why he continued his studies and went on to teach. Early work experience included designing buoys and marine structures for the Marine Department of the Dominion of Canada, work for the Canadian Pacific Railroad in design as well as serving as a construction superintendent, and as an engineer for a coal mining company in West Virginia. Within six years of graduation, he was appointed as chief engineer of the firm of Raymond & Campbell in Council Bluffs, Iowa, a bridge building firm where he got his first taste of solving practical bridge engineering problems.

While pursuing various sources of employment from 1878 to 1881, Dr. Waddell taught at his alma mater, RPI, and continued to develop his reputation as a theoretician. He also wrote papers on a wide range of subjects, drawing from his professional experience. Dr. Waddell's quickly rising stature in the engineering community and authoring of several practical engineering papers brought him the opportunity to serve as Chair of the Civil Engineering Department at the Imperial University of Tokyo, which was then in its infancy[7]. It was during his tenure at the Imperial University that Waddell wrote his first book, *The Designing of Ordinary Iron Highway Bridges*. Waddell went on to author many other works which leads to an abundance of available technical information and insight into his character gleaned from his unique casual writing style. Engineering peers give considerable useful feedback on Waddell's writings when publishing in the various technical journals. While there always is a degree of professionalism in the feedback, there is also competitiveness between engineers which must be considered. While Waddell's premier treatise, *Bridge Engineering*[8], covers a broad range of topics, the chapter on vertical lift bridges in Volume I is surprisingly sparse on technical detail, focussing more on showcasing Waddell's designs rather than giving much design guidance. Volume II gives a bit more general technical guidance in the chapter titled "General Specifications" but details are still limited. The sparseness of detail is explained in Waddell's preface of this work as follows:

"When Mr. Harrington and he met about the end of October (1914), it was decided that the author should take over writing of the proposed treatise, but should deal in a general way only with the subject of movable bridges, so that Mr. Harrington may some day write an exhaustive and detailed monograph thereon, as he is eminently capable of doing."
– J. A. L. Waddell, 1919[9].

Drawing on an old friendship with Professor William Burr, who had been his superior while teaching at RPI and had gone on to be an engineer with Phoenix Bridge Company, J. A. L. Waddell opened his private engineering practice on January 1, 1887 in Kansas City, Missouri. His consulting business was a private practice but he also served as a representative of Phoenix Bridge who sought to take advantage of the major westward expansion of railroads in the United States and thereby needed representation in the Midwest. Eventually, Waddell no longer needed his ties to the Phoenix Bridge Company and separated from them in 1892, at a time when it was difficult to reconcile his dual role as a consultant and a representative of a bridge manufacturer[10] [11]. At this time Waddell started to focus on his most noted design specialty, which would remain with his successor firm to this day, the design of movable bridges. This was not the only area where Waddell excelled, however, as he designed many monumental long-span cantilever truss bridges as well as long-span suspension and arch bridges.

Dr. Waddell experimented with many different movable bridge types and designed most types to some degree. Many designs were abandoned in favor of other schemes after preliminary engineering. In keeping with the standards of the time, the first movable bridges designed by Dr. Waddell were swing spans. He also designed double swing spans, bascules (including one with rolling counterweights), and double pull-back draws. Vertical lift bridges, which Dr. Waddell is most noted for, were just emerging as a viable design type at the time Waddell established his independent private practice. The vertical lift span ultimately became the movable bridge type, which Dr. Waddell is most known for.

Waddell was sole owner or senior partner of a series of six firms from the founding of his first private practice in 1887 until his death in 1938 [12] [13]. Waddell was active in the firm for over fifty years and "died with his boots on" at the age of 84. His firms included: J.A.L. Waddell (1887-1898), Waddell & Hedrick (1899-1907), Waddell & Harrington (1907-1915), Waddell & Son (1915-1920), J.A.L. Waddell (1921-1926), Waddell & Hardesty (1927-1945).[14]

Waddell moved his practice from Kansas City to New York City in 1920, aiming for a greater international presence as well as job opportunities on the East Coast of the United States. The Waddell name remained with the firm for seven years after his death when the name was changed to Hardesty & Hanover, a firm that continues to excel in the design of vertical lift bridges.

Dr. Waddell gained personal acclaim and recognition, receiving honorary degrees from McGill University, the University of Missouri, the University of Nebraska, the University of Puerto Rico and the Imperial University of Japan. The governments of Japan, China, Russia and Italy also honored him[15]. The eminent engineer appeared quite stately with his white hair, a large, brushy moustache and a variety of governmental and professional decorations on his chest.

Significance of the Vertical Lift Bridge

Prior to 1890, practically all major movable bridges were the swing span type. Swing spans were cost effective, functioned well where unlimited vertical clearance was required for tall-masted vessels and the center pivot pier did not pose an objectionable hazard to navigation. Bascule type bridges came into popular use in the 1890's where unlimited vertical clearance was still required and channels were of moderate width. Bascules were less economical for longer spans as the weight of the counterweight increases by a factor of three to five times the weight of the span thereby greatly increasing substructure costs and wind loads on an open leaf of a bascule posed large machinery loads. Vertical Lift Bridges fit in a niche where a wide channel is required yet unlimited vertical clearance is not required. As vertical lift bridges can be designed to raise 150 feet and higher, they can effectively be designed to open higher than essentially any vessel. Vertical Lift Bridges required relatively simple construction, small foundations and have moderate power requirements. Vertical lift bridges have the disadvantage of visually imposing towers and higher first cost for shorter spans due to the relatively expensive towers.

In *De Pontibus*[16], Waddell lists the advantages of vertical lift bridges as compared to rotating drawbridges:

> *1st A lift bridge gives one wide channel for vessels instead of the two narrow ones afforded by a center-pivoted swing bridge.*
>
> *2nd There are no land damages in the case of a lift-bridge, as the whole structure is confined to the width of the street. These land damages in the case of some swing-bridges amount to a large percentage of the total cost of structure.*
>
> *3rd Vessels can lie at the docks close to a lift-bridge, which they cannot do in the case of a swing-bridge; consequently with the former the dock-front can be made available for a much greater length between streets than it can with the latter.*
>
> *4th The time of operation for a lift-bridge is about 30% less than that for a corresponding swing bridge.*

Waddell goes on to list the advantages of a lift-bridge in comparison to a bascule or jack-knife draw, both of these being supposed to be without a center pier, as follows:

> *1st The lift-bridge can be made of any desired span, while in the case of the others the span is necessarily quite limited in length.*
>
> *2nd A lift-bridge can be paved while the others can not.*
>
> *3rd The lift-bridge is very much more rigid than any structure composed of two or more partially or wholly independent parts, a feature characteristic of the jack-knife bridge or the bascule without a center pier.*

> 4th *In a lift-bridge the operating machinery is much more simple; and, in case that it should ever get out of order, the span can be raised or lowered either by unbalancing, or by simple hand mechanism, or by both combined.*

While there have been changes in materials, machinery technology and electrical drive systems including skew control, Waddell's listing of advantages of the vertical lift bridge would be essentially unchanged one hundred years later.

The Duluth Bridge – A Winning Design Which Was Not Built

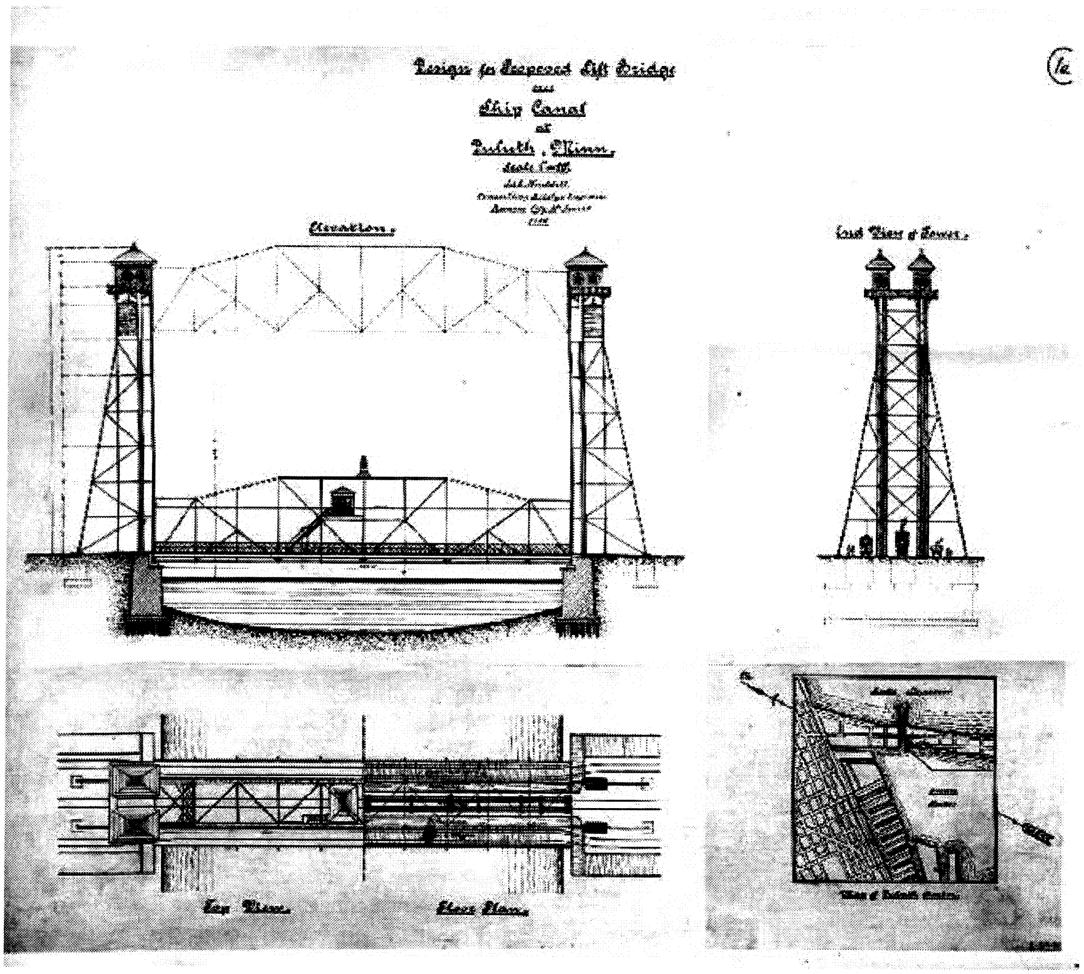
The first public display of Waddell's concept for a high-lift vertical lift span was in the competition for the design of a bridge over the Duluth Ship Canal. This competition drew an array of unique designs but Waddell's was the only vertical lift bridge design entered. The competition called for designs without a central pivot pier to hinder navigation. Solutions included single and double retractile bridges, bobtail swings, a retractile bridge supported on towers, pontoon swing bridges and a double leaf bascule with a center folding pier resting on a pedestal on the canal bottom. The judges awarded the prize to a retractile bridge designed by the firm of F. C. H. Arentz and L. E. Sangdahl but recommended building Waddell's vertical lift design pending later construction of a tunnel. Waddell's entry was a 250-foot long vertical lift span. While Waddell's entry was given serous consideration, the War Department ultimately ruled out any bridge containing a movable span[17].

When all was said and done, the bridge completed at the Duluth site in 1905 was an aerial transfer bridge consisting of an elevated fixed truss across which a gondola passed. This design, while used in Europe, was very unusual in the United States and eventually could not support the demands of traffic. Twenty-five years later, Waddell's vertical lift solution was affirmed for this site when the aerial transfer bridge was converted to a vertical lift bridge.

Halsted Street Bridge – First Modern Vertical Lift Bridge

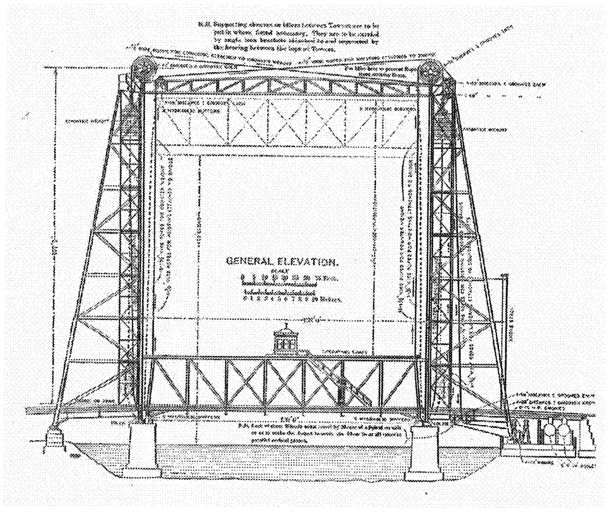
The South Halsted Street Bridge over the Chicago River was the first modern vertical lift bridge and the first vertical lift bridge of any size built in the United States. A detailed description of this bridge is given in the Transactions of the American Society of Civil Engineers, January 1895[18].

Several factors lead to the construction of this bridge. Firstly, the City of Chicago was directed by the War Department to replace a swing span, which had been knocked down on June 30, 1892, with a bridge which would not obstruct the waterway. Waddell, having developed a design for the Duluth Bridge only a year before, stood ready to quickly execute the design of a new vertical lift bridge to be constructed at South Halsted Street. He designed a vertical lift span with a 130 foot long Pratt Truss that could be lifted to a height of 155 feet above the river. The towers rose 217 feet above the water. The bridge was designed with a 34 foot wide roadway to carry vehicular traffic and a double track street railway and was also fitted with two seven-foot wide sidewalks.



Waddell's Proposed Vertical Lift Bridge over the Duluth Ship Canal, 1892 (Collection of Hardesty & Hanover, LLP, New York)

Operation of the lift span was by a stationary steam engine below the roadway, which powered operating ropes to pull up the span. Similarly, the steam engine drew up the counterweights to close the span. The machinery was originally intended to be in the tower, but the steam driven machinery selected by the contractor was not deemed suitable for the tower location and, therefore, the machinery was placed below the roadway. A backup engine was also supplied which could be actuated quickly, if necessary due to a breakdown. Cast iron counterweights were used to minimize the load on the machinery and balance chains were used to offset counterweight rope weight. Hydraulic buffers were used at the top of span travel and are adjustable for fine tuning the rate of deceleration. The hydraulic buffers were able to bring the span to rest smoothly even at its greatest



General Arrangement of the South Halsted Street Bridge over the Chicago River Completed in 1894 (Transactions of the American Society of Civil Engineers, January 1895) velocity of four feet per second. Spring loaded rollers at the tops and bottoms of the trusses guide the span. Water tanks were added on the span for adjustments of balance due to moisture, snow, etc. The tanks had a 19,000-pound total capacity and were normally partially full of water. Steam lines from the bridge powerplant could be used to keep the tanks defrosted in winter. Power requirements varied depending on friction at the sheave bearings, which was not well defined at that time. Waddell had to develop his own design parameters for this new type of movable bridge.

The operator's house above the span served as an observation point as it was only fitted with a "peeper" for observing ship clearances and a signaling device. Unfortunately, smoke from coal burning tugs quickly covered the peeper and blocked the view. No controls were provided in the operator's house. Roadway traffic control equipment was minimal. The specific problem of ship collision, which resulted in the need for the bridge in the first place, was addressed by incorporating collision resistant features in the bridge. Standard City of Chicago requirements including a protective nosing on the fascia intended to break the mast of a vessel and an inexpensive sacrificial wooden handrail were incorporated in the design. In addition, special break-away rollers were used on the lift span to allow the span to move out of the way is hit by a ships hull while sustaining minimal damage[19].

Turnbuckles were used for rope adjustment. Rope connections were made using pins so that the counterweight could be erected in the up position and the lift span moved into place and connected with pins[20]. This proved necessary as the ropes stretched two feet shortly after the bridge started regular operations. Adjustable pedestals were used under the rear columns to allow for differential settlement. These pedestals were complex spherical forgings with a threaded end for adjustment. This feature was considered important for this site where the front piers were founded on rock and the rear piers were on grillages supported on earth.

Waddell hoped for quick acceptance of the design and prepared designs for other vertical lift bridges over the next few years but none were built. The Halsted Street Bridge, a prototype for ensuing generations of lift spans, showed the basic concept to be a sound one with operation being better than was anticipated. Details, which needed improvement, were also noted for incorporation in future designs. In many ways the site of the Halsted Street Bridge, a narrow crooked river lined with industry, proved to be a perfect test site for the first vertical lift span.

Vertical Lift Bridge Design Variations

The early years of vertical lift bridge design were times of experimentation with novel machinery arrangements and development of one-of-a-kind engineering marvels. While the unique bridges of this period provided a great source of individual pride and material

South Halsted Street Bridge Details including operator's house, rope adjusters, counterweight chains, ship impact protection features (Transactions of the American Society of Civil Engineers, January 1895) for papers and books written by J. A. L. Waddell, John Lyle Harrington and their associates, the simple basic vertical lift bridge design was the one that eventually saw widespread use. In its purest form, a modern vertical lift span includes a counterweighted span, which lifts while remaining in a horizontal plane. Towers are used to provide the required height of lift based on the requirements of a specific application. Counterweight ropes passing over sheaves at the top of the towers connect the vertical lift span with the counterweights. A few vertical lift bridges were built which used chains or levers but these were atypical. Most spans incorporated wire ropes. Some variations on the basic design include:

1) Operating Machinery Types:
    a) Span Drive
    b) Tower Drive
    c) Four versus eight sheaves
2) Span Structural Systems:
    a) Truss
    b) Girder
    c) Skewed spans
3) Tower Structural Systems:
    a) Vertical Towers
    b) Sloped Back Tower Legs
    c) Overhead truss

Rare specialty type vertical lift bridges which vary significantly from the basic vertical lift design, include the double deck type lift span in which only the lower deck may be lifted, as in the case of the ASB Bridge at Kansas City, Missouri[21]. Another unique variant is the double deck type in which either the lower deck or both decks may be lifted. The only example of this type of bridge is the Steel Bridge in Portland, Oregon[22]. Both of these bridges were designed by Waddell & Harrington and are still in service today. While these movable spans are exemplary and novel, the designs proved too complex for widespread use. The specialty vertical lift bridges served a useful function where there are two primary groups of vessels navigating below, frequent openings of the lower deck are required for the shorter vessels and less frequent or no openings are required for taller vessels. The double deck type would normally require two types of users of the bridge, typically both railroad and vehicular use. Since a

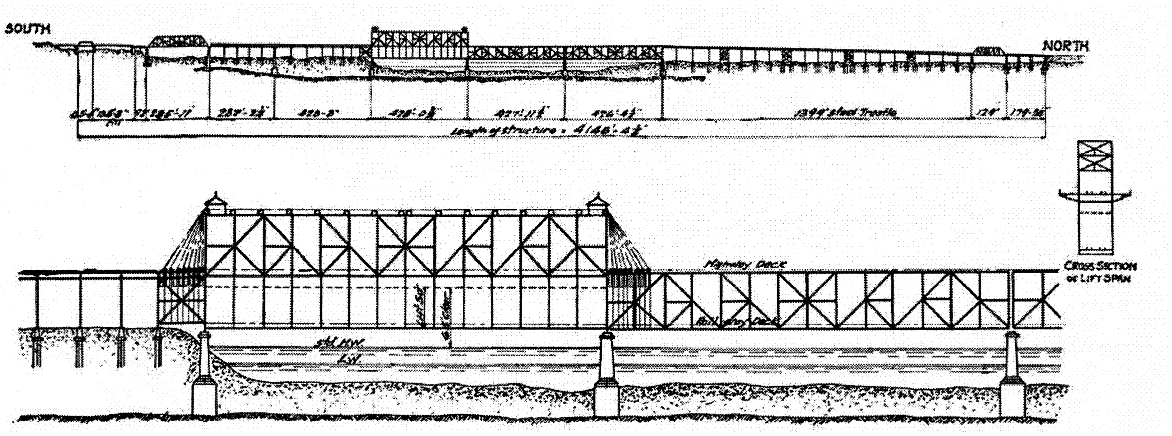
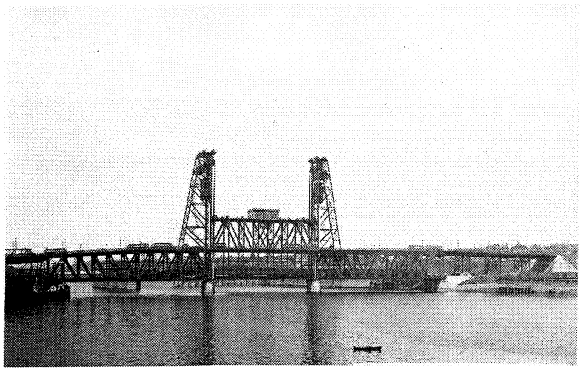
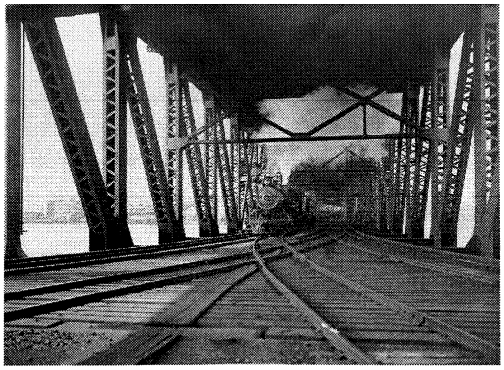


Figure 5 – ASB Bridge in Kansas City, MO, a unique lifting deck bridge (Waddell & Harrington Brochure, 1913)



Steel Bridge, Portland, Oregon, a double deck lift span with independent lower lifting deck (photo circa 1913) (collection of Hardesty & Hanover, LLP, New York)



Steel Bridge carrying Rail Traffic on the Lower Deck (photo circa 1913) (collection of Hardesty & Hanover, LLP, New York)

railroad has a tighter restriction on roadbed grade and therefore can not be elevated as high above the river, the railroad is placed on the lower deck. This arrangement also allows itself to other means of operation including leaving the lower deck in the open position and only lowering it when required for scheduled train passage. This is how the Steel Bridge is presently operated.

Many later vertical lift bridges designed by Harrington and others were referred to as the Waddell & Harrington Type[23]. This served to perpetuate the name of a partnership, which split some eight years after it had formed.

Vertical Lift Bridge Patents

Waddell patented many engineering inventions including the Waddell 'A' truss bridge, a plan for converting a single-track truss to a dual track structure, a suspension bridge braced by an inverted catenary, and a movable jetty structure in addition to a group of vertical lift bridge patents.
During the second half of the nineteenth century, many bridge firms patented their own bridge types and attempted to gain royalty profits and notoriety. Patents were issued for variations on key movable bridge types with some rather complex and impractical designs being patented. Many bridge patents resulted in only a handful of actual examples. The vertical lift bridge patents by Dr. J. A. L. Waddell proved to be more popular and were put into use for many years. Early developments in vertical lift bridges can be traced through the records of the U.S. Patent Office. Due to conflicting terminology, many patents listed for "Lift Bridges" actually refer to other types of movable spans, such as bascules, grouped under the generic term of lift bridges. Early lift bridge patents issued prior to 1919 are given in Table 1. Associated components which could be used with a lift bridge but do not represent an entire lift bridge system are given in Table 2.

Patent Number	Date Filed	Date Issued	Inventor	Title	Description	Application	Example
100,910	-	Mar. 15, 1870	Niel MacNeale	Improved Draw-Bridge	Lift Span elevated from below by hydraulic cylinders, screws or steam, may be counterweighted	Low Lifts	
134,338	-	Dec. 24, 1872	Squire Whipple	Improvement in Lift Draw-Bridges	Truss with telescopic deck lifted by ropes or chains at each panel point, power winch for speed. Used on Erie Canal	Low Lifts	
162,576	Aug. 25, 1874	Apr. 27, 1875	Andrew J. Post	Improvement in Lift - Bridges	Ctwted lift span operated by ropes from one side of the channel, synchronized & guided at each corner, integral gates	All Height Lifts	
225,775	June 19 1879	Mar. 23 1880	Enos B. Whitmore	Lifting Bridge	Very complex mechanism that combines counterweights, ropes, drums, and a hydraulic equalizing mechanism with submerged pipes, includes roller guides	Low Lifts	
431,101	Apr. 19, 1890	July 1, 1890	John F. Alden	Lift - Bridge	Telescopic deck, machinery above, rope adjustment with threaded rods, centering device	Low Lifts	
506,571	Nov. 10 1892	Oct. 10 1893	John A. L. Waddell	Lift-Bridge	Counterweighted Lift span driven by ropes with stationary engine, hydraulic buffers, roller guides, tower leg adjustment, ctwt chain, peeper to view channel	All Height Lifts	Halsted Street Bridge
635,394	May 5 1899	Oct. 24 1899	August Ruthenberg	Lift -Bridge	Hydraulic lift, synchronized by gearing with pipe and shaft below waterway, column-mounted racks provide lift	Low Lifts	
932,359	Aug. 3 1908	Aug. 24 1909	JAL Waddell JL Harrington	Lift-Bridge	Span drive lift bridge. Machinery moves with span. Operating drums lift the span.	Maximum Lifts	Keithsburg Bridge
952,486	Aug. 17 1908	Mar. 22 1910	JAL Waddell JL Harrington	Lift-Bridge	Fixed upper deck and lifting lower deck, cam type locking mechanism for posts.	Moderate Height	ASB Bridge
953,307	June 26 1908	Mar. 29 1910	JAL Waddell JL Harrington	Lift-Bridge	Tower Drive Lift Bridge, machinery in each tower with endless operating ropes to keep span level, provides rope tensioners, jaw type span locks, solenoid brakes, span guides, manual backup, can operate with only one machinery set	Maximum	Marine Parkway Bridge
1,027,477	Oct. 14 1910	May 28 1912	JL Harrington	Lift-Bridge	Independently Lifting upper and lowerr decks, lower deck raised, then, if needed, both may be raised		Steel Bridge
1,027,478	Nov. 7 1910	May 28 1912	John Lyle Harrington	Lift Bridge	Rack and pinion lifting mechanism, Counterweighted span with operating machinery on the span	Moderate Height	
1,038,226	May 1 1910	Sept. 10 1912	Joseph B. Strauss	Bridge	Counterweighted levers lift each end of the bridge	Moderate Height	
1,285,696	Oct. 10 1917	Nov. 26 1918	John Lyle Harrington	Lift-Bridge	Machinery on towerless lift span rotates drums at each end, drawing up a counterweighted lift span on columns	Low Lifts	

Table 1 – Early Vertical Lift Bridge Patents
Developed from the records of the United States Patent Office

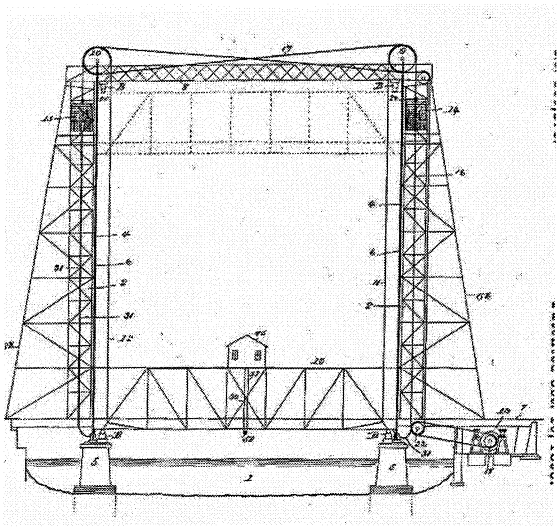
Patent Number	Date Filed	Date Issued	Inventor	Title	Description	Application	Example
417,481	May 2 1889	Dec. 17 1889	Latharo M. Friar	Lift - Bridge	Addition of retractible stairs for pedestrian access when the span is raised	Low Lifts	
469,314	Aug. 6 1891	Feb. 23 1892	George B. Clark	Shaft Coupling for Lift-Bridges	Adjustable coupling useful for lifting platforms when many ropes need adjustment	Low Lifts	
635,394	May 5 1899	Oct. 24 1899	August Ruthenberg	Lift -Bridge	Hydraulic lift, synchronized by gearing with pipe and shaft below waterway, column-mounted racks provide lift	Low Lifts	
1,003,901	Oct. 10 1910	Sept. 19 1911	John Lyle Harrington	Fluid Conduit for Lift-Bridges	Telescopic pipe allows utility to pass over a lift bridge in either the up or down position or while moving	All	
1,049,422	Nov. 20 1911	Jan. 7 1913	JAL Waddell JL Harrington	Lift Bridge	Means to carry fluid conduit across a lift bridge on trusses	All	City Waterway
1,067,169	Feb. 23 1912	Jul. 8 1913	John Lyle Harrington	Gate for Bridges	Independent oncoming and offgoing gates for lift spans gates pivot as they lower	All	
1,087,233	Sept. 26 1912	Feb. 17 1914	Ira Hedrick V. Cochrane	Counterweight	Collapsable counterweight to act as a secondary counterweight and offset rope weight	All	
1,234,021	Oct. 9 1915	Jul 17 1917	JL Harrington E. Howard L. Ash	Indicator	Height indicator which could be used for a vertical lift bridge	All	

Table 2 – Early Machinery and Miscellaneous Patents Applicable to Vertical Lift Bridges
Developed from the records of the United States Patent Office

Patents for lifting decks, which can be lifted while remaining horizontal, can be traced back to 1870[24]. However, most vertical lift bridge patents prior to 1893 were for vertical lift bridges intended for low lifts such as could be used over canals. An early impetus was the expansion of canal transportation in the United States and, in particular, the construction of the Erie Canal. The influence of the Erie Canal on early lift bridge design is particularly evident in the home cities of these patent-holders, which included Rochester, Albany and Utica, New York[25, 26, 27, 28]. While many of the early patents were quite novel, most were complex and impractical. On the other hand, Whipples 1872 Patent number 134,338 did prove useful and resulted in the construction of several low height lift bridges over the Erie Canal.

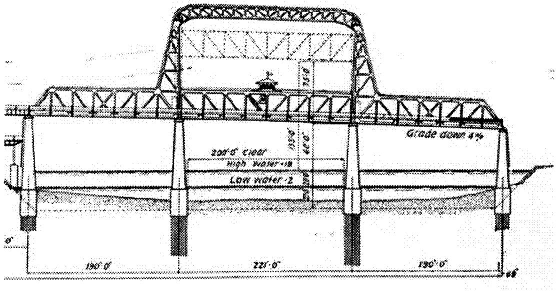
Dr. Waddell was the sole inventor for only one vertical lift bridge Patent, No. 506,571, "Lift Bridge" issued October 10, 1893[30]. This established a prototype for modern vertical lift bridge design and was essentially the design he used for the Halsted Street Bridge. The patent was very broad and addressed the basic concept of a counterweighted lift span with towers and driven by ropes with a stationary engine. The patent also included application of hydraulic buffers, roller guides, tower leg adjustment, counterweight chains and a peeper to vertical lift spans.

Later inventions bearing the name of J. A. L. Waddell list him as co-inventor along with John Lyle Harrington. These patents covered refinements and improvements of the basic vertical lift bridge design and, in particular, emphasized mechanical systems. The patents for which Waddell & Harrington were co-inventors included Nos. 932,359[31] issued in 1909; 952,486[32] and 953,307[33] issued in 1910; and 1,049,422[34] issued in 1913. The last of the patents listing Waddell & Harrington as co-inventors was applied for in 1911[35]. These patents included a) a span drive mechanism which can be used when the machinery is located on the lift span, b) a tower drive arrangement which can be used when the machinery is located in the fixed towers, c) a mechanism for a lifting deck, and d) a means to carry a fluid conduit across a lift span on trusses. The lifting deck system patent included a fixed truss supporting an upper deck and a telescopic lower deck similar to what was used at the ASB Bridge in Kansas City, Missouri. The means of carrying a fluid conduit was applied, in general, to the City Waterway Bridge and the Puyallup River Bridge in Tacoma, Washington [36].



Waddell's First Vertical Lift Bridge Patent (U. S. Patent Office)

Starting with the application for patent 1,027,479 on October 14, 1910 and continuing through 1918, John Lyle Harrington was issued five vertical lift bridge related patents as sole inventor as well as one with Howard and Ash as co-inventor. The first patent was for the double lifting deck arrangement which allowed either a lower telescopic deck to be lifted or both the upper and lower decks to be lifted together. This patent is similar to the design used on the Steel Bridge in Portland, Oregon. Harrington also was the inventor of the telescopic gas main carried across the Steel Bridge. (This feature has since been disconnected.) Apparently Dr. Waddell retained not only ownership of the joint patents, but also the patents issued to Harrington while they were a partnership. Upon the split of Waddell and Harrington in 1915, Waddell would have retained ownership of ten vertical lift patents (with the original Vertical Lift patent having expired in 1909, the effective number of patents he held would have been nine).



City Waterway Bridge, Tacoma, Washington (Waddell & Harrington Brochure, 1913)

Upon the split between Waddell and Harrington in 1915, J. A. L. Waddell claimed the rights to the vertical lift patents. His brochure[37] indicated: "Waddell and Son, Inc. has the sole right to all patents on the Vertical Lift

Bridge and bascule issued to the recent firm of Waddell & Harrington or to its members, and has several patents pending; it also has the exclusive use of patents on Bascule Bridges of Montgomery Waddell, and the use of the Brown Bascule Patents." The validity of this claim and how well this is enforced is uncertain since Harrington, Howard and Ash designed vertical lift bridges shortly after the split of Waddell & Harrington.

Vertical Lift Bridges Designed by Dr. J. A. L. Waddell's Firms – Early Dominance in the Field

In the early years of his firm, Waddell was still establishing a client base and ample conventional railroad bridge design and long span bridge design opportunities were available, making movable bridge design less of priority. Technical problems with the Halsted Street Bridge took several years to work out making it less that an ideal showpiece. Competition from other firms without rights to the Waddell Vertical Lift Patent, as well as political conditions further complicated matters. As a consequence, Waddell did not successfully implement any vertical lift bridge designs other than the South Halsted Street Bridge while first under the firm name of J. A. L. Waddell or later as Waddell & Hedrick. In subsequent years, Waddell proved to be far more active in vertical lift bridge design.

Tables 3a and 3b give a partial list of vertical lift bridges designed by Waddell and his firms. This list has been developed from successor company records and a number of third party sources. Since many of the early records have been lost, many less significant vertical lift bridges designed by Waddell have certainly been omitted. In addition to the seventy-four bridges listed, Waddell might also be attributed with the design of certain small vertical lift bridges designed by contractors and checked by his staff, further, many bridges designed by Waddell have multiple lifting spans which could be tallied separately. Shortly before his death, Waddell claimed to have designed more than ninety vertical lift spans[38]. Even with this listing, Waddell and his firms would be attributed as designers for seventy-four vertical lift bridges, many of which are still in existence today. At this rate, Waddell would have designed a new vertical lift bridge roughly every eight months over his fifty-one-year career. If it is considered that essentially all of Waddell's vertical lift bridge designs occurred after 1910, he produced at a rate of one new vertical lift bridge design every five months. The listing included those designs which were either built or were reported to have reached sufficient design completion to have been built. Preliminary designs or design contracts cancelled midstream are only listed when they are particularly significant. Current availability of plans varies.

It is interesting to note how dominant Waddell was in the area of vertical lift design in the early years. Ernest E. Howard's paper[39] of 1921 lists thirty-seven vertical lift bridges having been built to date. Shortridge Hardesty added eight more bridges to the list in his discussion of the paper[40], thereby bringing the list to forty-five as of 1921. Of these bridges, seventy-eight percent were designed by Waddell's firms. Ernest E. Howard would have been quick to point out, however, that Harrington, Howard and Ash designed many substantial vertical lift bridges and more than Waddell & Son from 1914-1921[41], but, he was not fully aware of the work being done by Waddell on the East Coast.

Waddell's Bridges fall into a range of categories with roughly 43 percent being highway bridges, 46 percent being Railroad Bridges and 11 percent being combined highway and railroad. Spans range from 39 feet to 544 feet in length and height of lift varies from 25 feet to 142 feet. Using 150-foot span length

#	Year Built	Name	Type	Feature Crossed	Location	Span Length	Lift Height	Current Status	Notes
J. A. L. Waddell (1887-1898)									
1	Designed 1892	Duluth Lift Bridge	Hwy	Duluth Ship Canal	Duluth, MN	250'		NB	Dept. of War Ruled out Movable Bridge
2	1894	Halsted Street Bridge	Hwy	Chicago River	Chicago, IL	130'	142'	R 1936	First Modern Lift Span
3	Designed 1894	Winner Bridge (later Fratt and ASB)	Hwy/RR	Missouri River	Kansas City, MO			NB	Financial problems prevented construction
Waddell & Hedrick (1899-1907)									
Waddell & Harrington (1907-1915)									
4	1909	Sand Point Bridge	Hwy	Pond Oreille	Sand Point, ID	86'	50'	R	First Vertical Lift for light highway use, manual operation
5	1910	Minneapolis & St. Louis Railway	RR	Mississippi River & Black Hawk Chute	Keithsburg, IL	234'	45'	R 1981	Should channel shift, towers can be relocated to lift another span Fire destroyed lift span, other spans remain, MP 1392.0
6	1910	Hawthorne Bridge	Hwy	Willamette River	Portland, OR	244'	110'	O	
7	1910	ASB Bridge	Hwy/RR	Missouri River	Kansas City, MO	425'	45'	O	Movable Lower Deck for RR, Rdwy Fixed, HAER Recorded, (now remote oper.)
8	1910	Ft Smith & Van Buren	Hwy/RR	Arkansas River	Ft. Smith/Van Buren, AK	196'	50'		Should channel shift, towers can be relocated to lift another span, MP 115.6
9	1911	Tehama Bridge	Hwy	Sacremento River	Tehama, CA	165'	59'	R 1977	Public wanted bridge preserved; Tehama County, MP 230.1
10	1911	Morgans LA & Texas RR	RR	Big Choctaw Bayou	Delcambre, Louisiana	50'	40'	O	Manual operation only, used as standard for Southern Pacific, now LA & Delta
11	1911	Steel Bridge	Hwy/RR	Willamette River	Portland, OR	212'	89'	O	Upper and Lower Decks Lift Independently
12	1912	City Waterway Bridge	Hwy	City Waterway	Tacoma, WA	221'	75'	O	NR 7/16/82, water main on overhead truss, MP 0.8
13	1912	Puyallup River Bridge	Hwy/RR	Puyallup River	Tacoma, WA	166'	112'	R	SR
14	1912	Penn Lines, W. of Pittsburgh No. 443	RR	Calumet River	Chicago, IL	2 @ 210'	98'	O	Twin Skewed Spans, designed for future 24' grade change, MP 1.4
15	1912	Columbia River Bridge	Hwy	Columbia River	Trail, BC	165'	47'		Towers omitted pending need for Navigation
16	1912	Little River Bridge	RR	Little River	Jonesville (Archie), LA	118'	41'	NO	Louisiana & Arkansas RR (later the Louisiana Midland Railway)
17	1912	Louisiana & Arkansas Railway	RR	Black River	Jonesville, LA	165'	53'		
18	1912	St. Louis, Iron Mountain & Southern	RR	St. Francis River	Memphis, TN / Cody, AK	162'	68'	NO	MP 29.6
19	1912	St. Louis, Peoria and Northwestern	RR	Illinois River	Pekin, IL	172'	39'	R	
20	1913	Red River Bridge	Hwy	Red River	Oslo, MN	140'	25'	R 1959	
21	1913	Pennsylvania Railroad No. 458	RR	Chicago River	Chicago, IL	273'	111'	NO?	Skewed, Owned by Amtrak, MP 3.8
22	1913	Southern Pacific Railway	RR	Willamette River	Salem, OR	134'	51'	NO	Should channel shift, towers can be relocated to lift another span, MP 84.3
23	1913	Northern Pacific Railway No. 10	RR	North Thompson River	Kamloops, BC	90'	53'	?	Plate girder, towers can be relocated due to channel shift
24	1914	Lake Shore & Mich. Southern	RR	Calumet River	Chicago, IL	2 @ 210'	98'	NO	Twin Skewed Spans, MP 1.3
25	1914	Great Northern Railway	RR	Missouri River	Snowden, Montana	296'	40'	NO	HAER Recorded, Burlington Northern, MP 1686.0
26	1914	Great Northern Railway	RR	Yellowstone River	Fairview, Montana	272'	40'	NO	NR, Burlington Northern Santa Fe, opened in 1914, local preservation effort, MP 8.9
27	1914	St. Johns & Quebec Railroad	RR	Oromocto River	Fredericton, New Brunswick	58'	56'		Plate Girder Span, preservation effort
28	1914	Caddo Lake Bridge	Hwy	Caddo Lake	Morringsport, LA	92'	49'	O	Manual Operation only, plate girder
Waddell & Son (1916-1920)									
29	1917	Don River Bridge	RR	Don River	Rustov, Russia	220'	127'	R?	Vladicaucase Railway, Curved rear tower legs
30	1917	Interstate Bridge (Pacific Highway)	Hwy	Columbia River	Portland, OR	275'	136'	O	HAER Recorded, Burlington Northern, MP 1686.0
31	1917	Pennsylvania Railroad (L&I)	RR	Ohio River/ L&P Canal	Louisville, KY	264'	33'	O	MP 376.6
32	1919	Market Street Bridge	Hwy	Cross Bayou	Shreveport, LA	54'	30'	R?	
33	1919	Red River Bridge	Hwy	Red River	Davidson, OK	54'		NB	
34	1919	Osage River Bridge	Hwy	Osage River	Huber's Ferry, MO	100'	33'	NB	Concrete Towers
35	1919	Lamb-Fish Lumber Co. Bridge	RR/Hwy	Tallahatchie River	Charleston, Mississippi	76'	46'	NB?	

Legend:

NR = National Register	O= Operational	R = Removed (year)	MP = River Mile Point
SR = State Register	NO = Non-Operational	NB = Not Built	

Developed from the records of Hardesty & Hanover, LLP
and also from References 56 through 66

Table 3a - Vertical Lift Bridges Designed By J. A. L. Waddell's Firms

#	Year Built	Name	Type	Feature Crossed	Location	Span Length	Lift Height	Current Status	Notes
J. A. L. Waddell (1921-1926)									
36	1921	Warrior River Bridge	Hwy	Warrior River	Tuscaloosa - Northport, AL	186'	36'		MP 129.2
37	1921	Cowlitz River Bridge (Allen St.)	Hwy	Cowlitz River	Kelso, WA	107'	42'	O	Emergency Operation Only, MP 5.5
38	1921	Southard Street Viaduct	Hwy	D&R Canal	Trenton, NJ	70'	28'	R 1950's	Machinery below plate girder deck, trapezoidal span
39	1921	Moss Bluff Bridge	Hwy	Calcasieu River	Lake Charles, LA	94'	35'	O?	Subconsultant, owned by Calcasieu Parish, MP 47.8
40	1922	Anguilla Bridge	Hwy	Big Sunflower River	Rolling Fork, Miss.	139'	47'		Subconsultant
41	1922	Bayou Colyell Bridge	Hwy	Bayou Colyell	Livingston Parish, LA	54'	36'	R	
42	1922	Mermentau River Bridge	Hwy	Mermentau River	Mermentau, LA			NB?	
43	1923	New York Central Railroad	RR	Niagara River	Grand Island, NY			NB	
44	1923	West Palm Beach Bridge #1	RR	W. Palm Beach Canal	West Palm Beach, FL	39'	40'	O	Florida East Coast Railway, MP 41.3, Phoenix Bridge
45	1923	St. Lucie Canal (Okeechobee)	RR	St. Lucie Canal	Canal Point, FL	63'	40'	O	Florida East Coast Railway, MP 38.0, Phoenix Bridge
46	1923	West Palm Beach Bridge #2	RR	W. Palm Beach Canal	Okeechobee, FL	55'	40'	O	Florida East Coast Railway, Okeechobee Ext., Br. P-171.84, MP 0.0
47	1924	Olden Avenue Viaduct	Hwy	D&R Canal	Trenton, NJ	76'	28'	R 1950's	Machinery below plate girder deck, skewed
48	1924	Memorial Bridge	Hwy	Piscataqua River	Portsmouth,NH-Kittery,ME	299'	128'	O	Similar to Ohio River Bridge
49	1925	Moscow Ferry Bridge	Hwy	Tombigbee River	Demopolis, AL	160'	42'	R?	MP 160.8, Featured in internet towboat photos
50	1925	Miami Canal Bridge	RR	Miami Canal	Hiahleah, FL	65'	60'	R	Florida East Coast Railway, No. 12.32, Phoenix Bridge
51	1925	Rantowels Bridge	RR	Rantowels Creek	Rantowels, SC	58'	30'	NO	Atlantic Coast Railroad, MP 1.1
52	1926	Central RR of New Jersey	RR	Newark Bay	Newark, NJ	2 @ 299'	100'	R 1980	HAER Recorded, MP 0.7
						2 @ 211'	100'		
Waddell & Hardesty (1927-1945)									
53	1928	Snohomish River Bridge	Hwy	Snohomish River	Everett, Washington	141'	40'	O	
54	1928	Carlton Bridge	Hwy/RR	Kennebec River	Bath, Maine	141'	125'	RR Only	Double Deck with Hwy over RR
55	1928	Delaware Lackawana & Western	RR	Hackensack River	Jersey City, New Jersey	198'	95'	O	Path-Hack Bridge 4.95, MP 3.4
56	1929	Eagle Avenue Bridge	Hwy	Cuyahoga River	Cleveland, OH	216'	82'	O	Major retrofit, MP 2.5
57	1929	San Francisco Toll Bridge	Hwy	San Francisco Bay	San Mateo, CA	298'		R 1968	Route 92, San Mateo-Hayward
58	1930	Southern Pacific Railway (Suisun)	RR	Carquinez Strait	San Francisco, CA	328'	64'	O	71' clear when closed, MP 7.0
59	1930	Pennsylvania Railroad	RR	Newark Bay	Jersey City, New Jersey	323'			
60	1930	Pennsylvania Railroad Br 4.25	RR	Hackensack River	Jersey City, New Jersey	332'		O	NJ Transit
61	1930	Pennsylvania Railroad Br 4.21	RR	Hackensack River	Jersey City, New Jersey	206'	124'	O	Upper Hackensack - CSX/NS? MP 3.1
62	1933	Hudson River Bridge	Hwy	Hudson River	Albany, NY	341'	98'	R 1970	MP 145.2
63	1933	Hudson River Bridge	Hwy	Hudson River	Troy, NY	341'	78'	NO	MP 150.2
64	1934	Dneiper River Bridge	Hwy/RR	Dneiper River	Dniepropetrovsk, Ukraine	270'		R?	lifting deck
65	1935	NYNH&HRR	RR	Cape Cod Canal	Massachusetts	544'		O	subconsultant
66	1935	Aluminum Bridge Investigation	RR	-	-	544'		NB	Study for Proposed Aluminum Span
67	1935	Meridian & Bigbee River Railway	RR	Tombigbee River	Naheola, Alabama	161'	47'		MP 132.3
68	1935	Pennsylvania Railroad	RR	Passaic River	Newark, NJ	230'	114'	O?	3 track Railway, owned by Amtrak, MP 5.0
69	1937	Pennsylvania Railroad	RR	Passaic River	Newark, NJ	230'	114'	O?	2 track Railway, owned by Amtrak, MP 5.0
70	1937	Pennsylvania Railroad	RR	Passaic River	Newark, NJ	230'	114'	O?	1 track Railway, owned by Amtrak, MP 5.0
71	1937	Marine Parkway Bridge	Hwy	Rockaway Inlet	Brooklyn/Queens, NY	540'		O	NR Eligible, Under Rehabilitation
72	1938	Torrence Avenue Bridge	Hwy	Calumet River	Chicago, IL	276'	95'	O?	Skewed Span, subconsultant, MP 5.3
73	1940	Columbus Road Bridge	Hwy	Cuyahoga River	Cleveland, OH	240'	80'	O	sloping deck, HAER Recorded, subconsultant to W. Watson, MP 1.5
74	1940	Carter Avenue Bridge	Hwy	Cuyahoga River	Cleveland, OH	220'	75'	O	HAER Recorded, subconsultant to W. Watson, MP 2.0

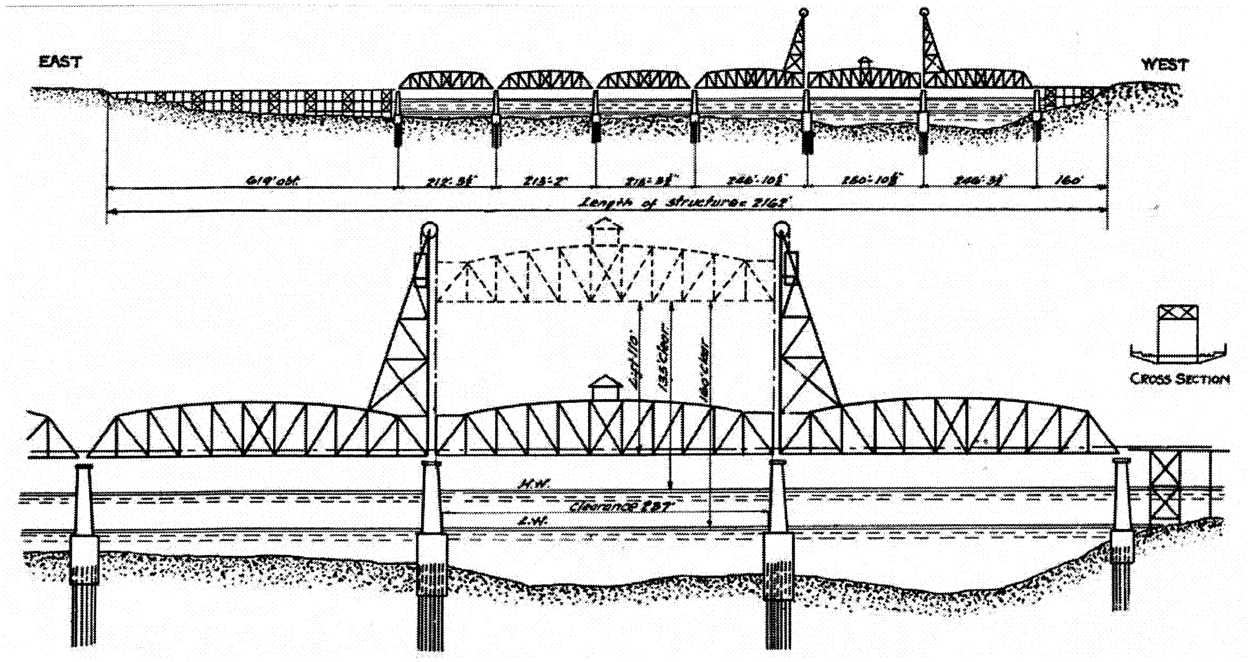
Legend:

NR = National Register	O= Operational	R = Removed (year)	MP = River Mile Point
SR = State Register	NO = Non-Operational	NB = Not Built	

Developed from the records of Hardesty & Hanover, LLP and also from References 56 through 66

Table 3b - Vertical Lift Bridges Designed By J. A. L. Waddell's Firms

to distinguish between short and long span vertical lift bridges, it can be seen that roughly 60 percent of the vertical lift bridges designed by J. A. L. Waddell were long span lift bridges. The oldest vertical lift span designed by Waddell still in existence today is the Hawthorne Bridge over the Willamette River in Portland, Oregon, which was built in 1910.



Hawthorne Bridge, Portland, Oregon, completed in 1910 (Waddell & Harrington Brochure, 1913)

Hawthorne Bridge, Portland, Oregon – Oldest Surviving Waddell Vertical Lift Bridge

The Hawthorne Bridge, designed by Waddell & Harrington, has a 244-foot long main span which is capable of a 110-foot vertical movement in 50 seconds under electric power. The towers rise 165 feet above the waterway[42 43]. The bridge was built for the City of Portland in 1910 to replace an earlier wooden span, which had burned down[44]. The new bridge originally provided two wagonways, a double track street railway and two footwalks. The simple span drive arrangement with operating machinery located on the lift span has proven very reliable. Early records showed this bridge to operate more quickly and cost less per operation than the swing and bascule bridges in the same area[45]. Since this bridge is the lowest lift bridge over the Willamette River in Portland, it is opened the most frequently. The Bridge currently carries roughly 30,000 vehicles per day in four lanes and opens for navigation an average of 200 times per month. The span has been opened over 100,000 times in its life[46]. Sidewalks on the bridge, recently widened to accommodate bicyclists, provide an important urban link.

The Hawthorne Bridge is an example of how a well-designed bridge can, if given proper maintenance, provide service for a very long service life. The Hawthorne Bridge was repaired, repainted, resurfaced and had a widened sidewalk added in 1999. As a result, the 91 year-old span should easily make it past 100 years.

The Armor, Swift, Burlington Bridge, Kansas City, MO – A novel Design with a Long History

"It would be a great satisfaction to the author to complete this bridge because of the novel design for the lifting deck" - J. A. L. Waddell, *De Pontibus*, 1898[47]

The ASB Bridge, designed by Waddell & Harrington, is a unique long-span lifting deck bridge with the upper deck fixed for highway traffic and a movable lower railway deck with posts, which telescope into the roadway truss. Completed in 1912, the ASB Bridge is eligible for the National Register of Historic Places and is HAER Recorded[48]. The railroad portion of the bridge has recently been rehabilitated including the lift span and the deteriorated roadway deck portion removed. The lift span remains operational today.

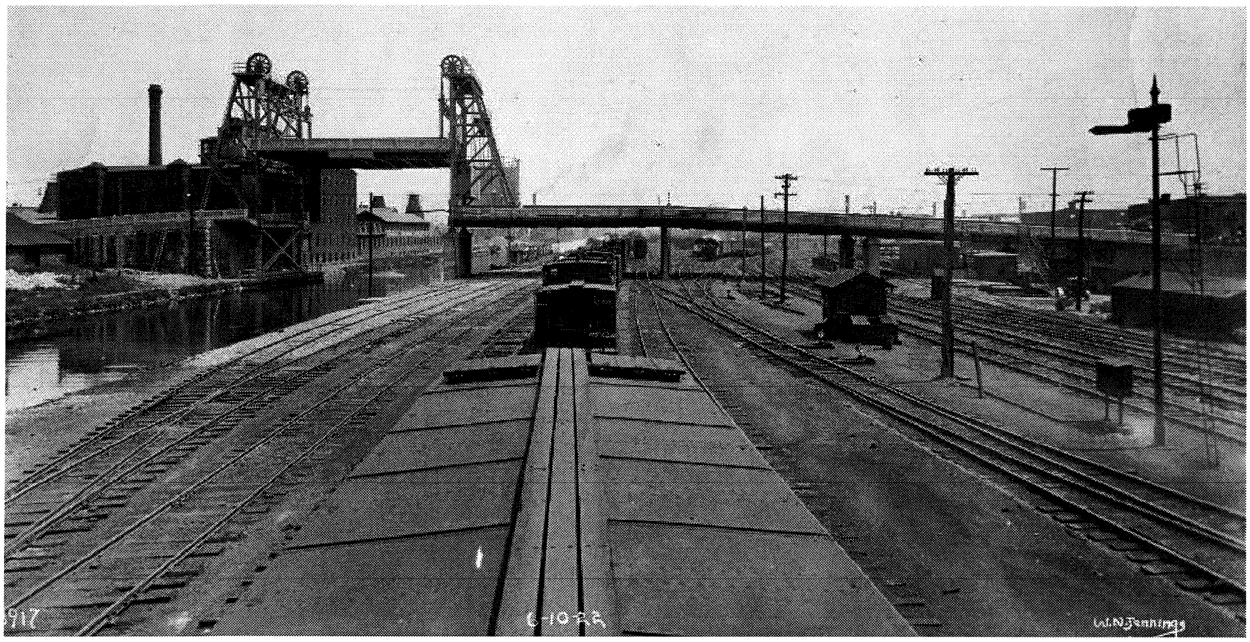
One of the first consulting jobs for the recently independent office of J. A. L. Waddell was the design of a fixed bridge over the Missouri River for the Wabash, St. Louis and Pacific Railroad Co. Construction according to Waddell's design was halted due to financial difficulties after completion of the substructure in 1890. Waddell was retained by the new owner of the substructure to design a lifting deck type bridge in 1894. This second design was referred to as the Winner Bridge after the then current owner of the railroad. This bridge was a pin-connected eyebar truss with cast iron counterweights at each panel point and movable posts passing outside of the supporting truss. Shafting extending from a central machinery house was proposed to operate the span[49]. The design was again halted due to financial difficulties.

The third owner of the bridge piers, Mr. Fratt of the Union Depot, Bridge and Terminal Railway Company approached Waddell in 1907 to update the earlier design for a lifting deck type bridge. John Lyle Harrington suggested improvements to the machinery, switching to operating ropes rather than shafting, moving the counterweights to the end of the span and switching them to less costly concrete, and substituting telescopic posts. Even the revised scheme had its skeptics and a large operating model had to be built to convince the railroad to accept the novel design[50].

One interesting feature of the bridge includes devices that automatically lock each telescopic member once it has reached its fully lowered position. When raised, the span provides a vertical clearance of 55 feet over a 435 foot wide channel. The channel width was more than would otherwise have been required due to the need to reuse existing piers [51]. The fixed upper deck allowed an uninterrupted flow of vehicular traffic to flow and accomodated utilities.

Southard Street Viaduct and Olden Avenue Viaduct, Trenton, NJ – Waddell Moves to the East Coast

The Delaware & Raritan Canal had been in existence for many years when Mercer County approached Waddell to design two new bridges to span the canal in Trenton, New Jersey at Southard Street and Olden Avenue[52] [53]. The projects included long viaducts over the railyard flanking the canal but the centerpiece of each of these projects was a small vertical lift span over the canal to replace an earlier swing span. This was essentially the first vertical lift bridge design project for Waddell after relocating his office to New York. The plans for these bridges bear the names Waddell & Son and J. A. L. Waddell Consulting Engineer respectively. This was the first of many vertical lift bridges designed by Waddell for the East Coast. The Southard Street Viaduct was completed in 1922 and the Olden Avenue Viaduct in 1924. The



Southard Street Viaduct, Trenton, New Jersey, Completed 1922 shortly after Waddell Relocated his Office to New York (photo 1922) (collection of Hardesty & Hanover, LLP, New York)

parallel viaducts were several city blocks apart and crossed the same waterway and rail yard. Due to the small size of the lift spans, 70 and 76 feet in length respectively, plate girders were used rather than trusses for the lift span. Machinery was arranged below the deck level. A unique feature of these bridges is their skewed decks. While the Olden Avenue Viaduct Bridge deck is a parallelogram, the Southard Street Viaduct deck is trapezoidal to conform to the approach alignment. Marine traffic required that the bridges lift only 28 feet.

Key Engineers working with Dr. J. A. L. Waddell

Another key contribution of Dr. Waddell to vertical lift design, as well as to the design of bridges in general, was his ability to inspire other engineers working in his employ to either excel while remaining with his firm or strike out on their own to lead other firms. Very few bridges are the sole work of one engineer. In the Waddell & Harrington years, John Lyle Harrington certainly made significant contributions to the machinery design and was critical to the smooth operations of the home office while Waddell spent much of his time on the road. Legions of staff engineers supported each of these more visible engineers, providing the necessary detail designs.

Southard Street Viaduct, Trenton, New Jersey, view from roadway level (photo 1922) (collection of Hardesty & Hanover, LLP, New

Many notable bridge engineers worked at the firm of J. A. L. Waddell including John Lyle Harrington. Harrington worked for the firm as a student, later joined the firm in 1895, and, after working for several other companies became a partner with Dr. Waddell in 1907. After his resignation from the partnership with Waddell, Harrington went on to open his own firm, Harrington, Howard & Ash in 1915 and later Harrington & Cortelyou. Harrington & Cortelyou is an engineering firm in Kansas City, which is still active in the movable bridge field today. Frank M. Cortelyou, Sr was also an employee of Waddell & Harrington, having joined the firm in 1908. Subsequently Harrington, Howard & Ash became Ash, Howard, Needles & Tammen and later Howard, Needles, Tammen & Bergendoff, who are also active today in the movable bridge field. Ernest E. Howard was employed with Waddell & Harrington in 1901, and Henry Casper Tammen was employed with the firm in 1907[54] [55].

Ira G. Hedrick started as chief draftsman with the firm of J. A. L. Waddell, later became a partner with him in 1899 and later went on to form the firm of Hedrick & Hedrick. The namesakes of the present firm of Hardesty & Hanover, LLP are Shortridge Hardesty and Clinton D. Hanover. Shortridge Hardesty started with Waddell & Harrington in 1908, and Clinton D. Hanover started with Waddell & Hardesty in 1924. Both Hardesty and Hanover both went on to become well known movable bridge engineers in their own right.

Preservation Issues

Many of the earlier bridges designed by Waddell are endangered. Many have been removed over the past twenty to thirty years. Locating and documenting remaining examples itself is a difficult task. Those examples that are well maintained tend to still be in service today. The lift bridges in the Portland, Oregon area are exceptional examples of preservation of this resource. Some removals have resulted from neglect, some from functional obsolescence for reasons of substandard lane width, some due to changing needs of navigation, others have been lost to accidents and at least one fell victim to an arsonist. Preservation is a particularly daunting task with Waddell's vertical lift bridges since many are owned by railroads and are in remote locations out of the public eye and less regulated than publicly owned structures.

As there is so much contemporary material written by and about Dr. Waddell and there is such a broad range of bridge designs to his credit, this paper is merely a beginning. Contributions by others will be appreciated, especially from firms claiming Waddell as their founder.

Footnotes:

[1] J. A. L. Waddell, "The Advisability of Instructing Engineering Students in the History of the Engineering Profession," *Annual Meeting of the Society for the Promotion of Engineering Education*, (1903), reprinted in *The Principal Professional Papers of Dr. J. A. L. Waddell,* John Lyle Harrington (Ed.), (New York: Virgil H. Hewes Press, 1905), Pg. 189

[2] John Lyle Harrington (Ed.), *The Principal Professional Papers of Dr. J. A. L. Waddell* (New York: Virgil H. Hewes Press, 1905): v

[3] John A. Schultz, "Remember the Past to Inspire the Future", *Proceedings of the Fifth Biennial Symposium, Heavy Movable Structures, Inc*, 1994

[4] Hardesty & Hanover, *One Hundred Years of Bridge Engineering, 1887-1987*, (brochure) (1987)

[5] J. A. L. Waddell, *Bridge Engineering* (in Two Volumes), (New York: John Wiley & Sons, Inc., 1916), Vol. 1: 717

[6] Harrington, 1-2 (see n. 2)

[7] Ibid., 3.

[8] Waddell, *Bridge Engineering*

[9] Ibid., viii

[10] Harrington, 4-5 (see n. 2)

[11] Thomas R. Winpenny, *Without Filing and Chipping, An Illustrated History of the Phoenix Bridge Company* (Easton, PA: Canal History and Technology Press, 1996)

[12] "J. A. L. Waddell dies at 84," *Engineering News Record*, (March 10, 1938):354

[13] "John Alexander Low Waddell, Hon. M. Am. Soc. C.E. 1854-1938," *Civil Engineering*, (April 1938): 286

[14] Genealogy of Hardesty & Hanover as compiled from company records, courtesy of Hardesty & Hanover, LLP, New York

[15] "A Kansas City Engineer Who Has Bridged the World," *Kansas City Journal-Post*, (June 22, 1924)

[16] J. A. L. Waddell, *De Pontibus: A Pocket Book for Bridge Engineers, Second Edition* (Brooklyn, NY: The Scientific Press, 1914): 113

[17] "Competitive Designs for a Draw-Bridge over the Duluth Ship Canal, Duluth, Minn.," *Engineering News*, (October 27, 1892), pg. 390-391

[18] J. A. L. Waddell, "The Halsted Street Lift-Bridge," *Transactions of the American Society of Civil Engineers, No. 742, Volume XXXIII*, (January 1895)

[19] Ibid., 534

[20] T. W. Heermans, Esq., "Discussion of the Halsted Street Lift-Bridge," *Transactions of the American Society of Civil Engineers, No. 742, Volume XXXIII*, (January 1895): 568

[21] Waddell & Harrington, Consulting Engineers, *Bridge over the Missouri River at Kansas City, MO – UDB&TRR Co.*, (Contract Plans for ASB Bridge), (Kansas City, MO, 1910)

[22] Waddell & Harrington, Consulting Engineers, *Willamette River Bridge, Portland Ore*, (Contract Plans for Steel Bridge), (Kansas City, MO, 1910)

[23] George A. Hool and W. S. Kinne, *Movable and Long Span Steel Bridges*, (New York: McGraw Hill, 1923)

[24] Niel MacNeale, Inventor, *Patent 100,910*, United States Patent Office, Issued March 15, 1870

[25] Squire Whipple, Inventor, *Patent 134,338*, United States Patent Office, Issued December 24, 1872

[26] Andrew J. Post, Inventor, *Patent 162,576*, United States Patent Office, Issued April 27, 1875

[27] Enos B. Whitmore, Inventor, *Patent 225,775*, United States Patent Office, Issued March 23, 1880

[28] John F. Alden, Inventor, *Patent 431,101*, United States Patent Office, Issued July 1, 1890

[29] Post, (see n. 21)

[30] John A. L. Waddell, Inventor, *Patent 506,571*, United States Patent Office, Issued October 10, 1893

[31] J. A. L. Waddell and John Lyle Harrington, Co-Inventors, *Patent 932,359*, United States Patent Office, Issued August 24, 1909

[32] J. A. L. Waddell and John Lyle Harrington, Co-Inventors, *Patent 952,486*, United States Patent Office, Issued March 22, 1910

[33] J. A. L. Waddell and John Lyle Harrington, Co-Inventors, *Patent 953,307*, United States Patent Office, Issued March 29, 1910

[34] J. A. L. Waddell and John Lyle Harrington, Co-Inventors, *Patent 1,049,422*, United States Patent Office, Issued January 7, 1913

[35] Ibid.

[36] *Waddell & Harrington, Consulting Engineers*, (brochure) (circa 1913)

[37] *Waddell & Son, Consulting Engineers*, (brochure) (circa 1916)

[38] "John Alexander Low Waddell", *Civil Engineering,* (January 1937): 77

[39] Ernest E. Howard, "Vertical Lift Bridges," Transactions of the American Society of Civil Engineers, Volume LXXXIV, (1921): 585-586

[40] Shortridge Hardesty, "Discussions on Vertical Lift Bridges" *Transactions of the American Society of Civil Engineers, Volume LXXXIV*, (1921) pg. 633

[41] Howard : 589 (see n. 39)

[42] *Waddell & Harrington, Consulting Engineers*, (brochure) (circa 1913)

[43] Sharon Wood and Jay Dee Alley, The Portland Bridge Book, (Portland, OR: Oregon Historical Society Press, 1989)

[44] Website:http://www.multnomah.lib.or.us/bridge/hawthorne_bridge/hawinfo.html, Multnomah County Bridges

[45] Howard : 589 (see n. 39)

[46] Multnomah County, (see n. 44)

[47] J. A. L. Waddell, *De Pontibus: A Pocket Book for Bridge Engineers, First Edition* (Brooklyn, NY: The Scientific Press, 1898)

[48] Jean P. Yearby, *Armour, Swift, Burlington Bridge (A. S. B.), HAER No. MO-2*, (National Park Service, Historical American Engineering Record: 1984)

[49] Waddell, *Bridge Engineering:* 723-728

[50] Howard : 602-605, (see n. 39)

[51] Ibid.

[52] Waddell & Son, Inc., Consulting Engineers, *Southard Street Bridge over Delaware & Raritan Canal, Trenton, New Jersey for County of Mercer*, (Contract Plans), (New York, 1921)

[53] J. A. L. Waddell, Consulting Engineer, *Olden Avenue Viaduct over Delaware & Raritan Canal, Trenton, New Jersey for County of Mercer*, (Contract Plans), (New York, 1922)

[54] Genealogy of Hardesty & Hanover as compiled from company records, courtesy of Hardesty & Hanover, LLP, New York

[55] Kathi Ann Brown, *Diversity by Design, Celebrating 75 Years of Howard Needles Tammen & Bergendoff, 1914-1989,* (brochure) (Howard Needles Tammen & Bergendoff: 1989)

[56] *Bridges over the Navigable Waters of the United States, Part 1, Atlantic Coast*, (United States Army Corps of Engineers, 1961)

[57] *Bridges over the Navigable Waters of the United States, Part 2, Gulf and Mississippi River System*, (United States Army Corps of Engineers, 1961)

[58] *Bridges over the Navigable Waters of the United States, Part 3, Great Lakes*, (United States Army Corps of Engineers, 1961

[59] *Bridges over the Navigable Waters of the United States, Atlantic Coast*, (United States Department of Transportation, United States Coast Guard, Publication Number COMDTPUB P16590.1, 1984)

[60] *Bridges over the Navigable Waters of the United States, Great Lakes*, (United States Department of Transportation, United States Coast Guard, Publication Number COMDTPUB P16590.3, 1984)

[61] *Bridges over the Navigable Waters of the United States, Pacific Coast*, (United States Department of Transportation, United States Coast Guard, Publication Number COMDTPUB P16590.4, 1984)

[62] *Code of Federal Regulations, Title 33, Volume 1, Part 117, Drawbridge Operation Regulations*, (U. S. Government Printing Office, revised July 1, 2000)

[63] Dwight A. Smith, James B. Norman, Pieter T. Dykman, *Historic Highway Bridges of Oregon* (Portland, OR: Oregon Historical Society Press, 1989)

[64] Kevin Murphy, Greg Fitzsimmons and Fredric L. Quivik, *Snowden Bridge (Nohly Bridge), HAER No. MT-27*, (National Park Service, Historical American Engineering Record: 1984)

[65] Bernard C. Winn, *California Drawbridges (1853-1995), The Link to California's Maritime Past* (San Francisco, CA: Incline Press, 1995)

[66] Michael M. Palmieri, *Louisiana Rail Site*, http://Lrs.railspot.com

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