Alfred L. Rives and the Cabin John Bridge: Creating an Unprecedented 67m Masonry Arch at Mid-Nineteenth Century

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ABSTRACT: The Cabin John Bridge is a masonry arch of 67m span, built from 1857 to 1863 to carry the Washington Aqueduct over the valley of Cabin John Creek. This paper examines the role of Alfred L. Rives, an 1854 graduate of *Ecole des Ponts et Chaussees*, in the design and construction of the bridge. The inspiration for the long-span design of the Cabin John Bridge was the Grosvenor Bridge, completed at Chester, England in 1834. For structural analysis, Rives adopted the graphical statics method proposed by Mèry in 1840. Mèry's design acceptance criteria were based on a rigorous understanding of the lower bound theorem of limit state analysis. Rives designed the center for the bridge, devised the construction technology, and supervised its construction from 1857 until the *keying* of the arch on 4 December 1858.

INTRODUCTION

Fig. 1 shows the Cabin John Bridge (CJB), located just outside Washington, D.C. It is masonry circular arc with a central angle of 110°, an intrados radius of 40.9*m*, and a span of 67*m*. Construction of the bridge began in 1857 but was suspended several times because of lack of funding and the Civil War. Therefore the bridge was not completed until late in 1863. Although a masonry arch with an estimated span of 72*m* existed over the Adda River at Trezzo, Italy from about 1377 to 1417 (Baker 1909; Sejourne 1913), the CJB was the longest single-span masonry arch in existence in 1864 and remained so until completion of the Adolphe Bridge in Luxembourg in 1903. The CJB, part of the Washington Aqueduct (WA) bringing water from the Great Falls of the Potomac River to Georgetown and Washington, remains the longest single-span masonry arch in the U.S. The CJB still carries an aqueduct conduit over the ravine of Cabin John Creek, although supplemented by another conduit, parallel to the first, built in the 1920's.

Figure 1: Cabin John Bridge

At present, under normal operating conditions, both conduits carry water (Gamby, pers. comm.). Therefore the original conduit within the spandrel area of the CJB has an enviable record of carrying water for over 140 years. The bridge was designated a National Historic Civil Engineering Landmark (NHCEL) by the American Society of Civil Engineers (ASCE) in 1972.

Despite the uniqueness, importance, and performance of the CJB, historical literature provides no explanation and context for its design. Drawings of the graphical analysis of the CJB have been published but without discussion of assumptions and design acceptance criteria. Many of its important details, its materials, and the construction technologies that were used have not been explained. Importantly, the respective roles of Montgomery C. Meigs, the chief engineer of the WA, and Alfred Landon Rives, his assistant engineer, have not been critically assessed. This paper addresses these issues and provides for the first time relevant facts on Rives' education. In the process, French and British influences on American masonry arch design practices at mid nineteenth century are revealed.

MONTGOMERY C. MEIGS AND ALFRED L. RIVES

Montgomery C. Meigs was born on 3 May 1816 in Augusta, Georgia, but grew up in Philadelphia, and graduated from West Point in 1836. In the following year, he became a member of the elite Corps of Engineers and subsequently helped build fortifications at Detroit, Rouses Point on Lake Champlain, on the Delaware River, and at other posts (Ways 1996). In November 1852 Lieutenant Meigs was ordered to perform a study to determine "an unfailing and abundant supply of good and wholesome water" for Washington (Meigs 1853). Meigs concluded that the only adequate source was the Potomac River at Great Falls, Maryland. His plan required two long-span aqueduct bridges to cross Cabin John Creek and Rock Creek. For the aqueduct bridge over Cabin John Creek, Meigs proposed "six semi-circular arches of 60 feet span" (Meigs 1853). This conceptual design followed the precedent of the Harlem River crossing of the Croton Aqueduct (Lankton 1978). Immediately following his report, Meigs was promoted to the rank of Captain and in March 1853 Meigs was appointed chief engineer of the WA as well as the U.S. Capitol Extension (Macqueen 1934; Ways 1996; Dickinson et al 2001). Meigs served as chief engineer almost continuously until 1861, when the Civil War led to his appointment as quartermaster general of the Union army (Weigley 1959).

Alfred Rives was born in Paris on 25 March 1830, while his father was U.S. minister to France. His childhood, however, was spent at the family home, called Castle Hill, in the piedmont region of Virginia, near Charlottesville. He was tutored at home until 14, and then attended Concord Academy in Caroline County, VA for two years. Rives then enrolled at Virginia Military Institute (VMI), graduating in two years, 6th in a class of 24 but first in engineering. He briefly enrolled at the University of Virginia but left to accompany his parents to France in 1849, when his father was again appointed minister. No doubt Rives wanted to study engineering in France, then the acknowledged leader in the theoretical training of engineers. His mother recalls that Alfred, "though only 19, had proposed to himself to follow the career of the world-renowned Stevenson, whose fame and power were then at their zenith" (Rives, J.P.W. 1871). At the mid nineteenth century, training of the elite French corps of engineers normally consisted of theoretical preparation at the *École Polytechnique* and then additional study at one of the *écoles d'application*, such as the École des Ponts et Chaussées (EPC). Up to 1851, EPC enrolled only Frenchmen (Lundgreen 1990; Saquet, pers. comm.). Rives' mother recalls that: "With great difficulty his father obtained for him an entrance into the École des Ponts et Chaussées" (Rives, J.P.W. 1871). Alfred in fact passed a rigorous entrance examination and was formally admitted as an "élève externe" on 11 July 1851 (Saquet, pers. comm.). The EPC entering class of 1851 consisted of ten "élèves internes," all graduates of the *École Polytechnique*, and two "élèves externes," Rives and a Polish national, Victor Hube (Saquet, pers. comm.).

Rives family papers at the University of Virginia (Rives 1853-1860) include a study entitled "Concours de Grand Pont," a competitive design project/exam written by Rives while a student at EPC. Here Rives remarked on the Grosvenor Bridge over the River Dee at Chester, a record-setting masonry arch with a span of 61*m,* opened to the public in 1834 (ICE 1842). The paper also contains an explanatory section on the "Theorie de M. Mèry," which was a graphical analysis method for masonry arches published in the *Annales des Ponts et Chaussées* (Mèry 1840).

By his final year in 1853-1854, Rives had accomplished a remarkable academic feat: he had risen to the top of his class, besting all his classmate graduates of *École Polytechnique*. In recognition of his accomplishment, the French minister of public works approved a present of 150 volumes of technical books, including the complete collection of the *Annales des Ponts et Chaussées*. Journal entries and letters suggest that Rives kept the *Annales* in the WA Engineering Department. Rives, the first American graduate in the register of EPC, received his diploma on 21 December 1854 (Saquet, pers. comm.).

Rives was hired by Meigs as an assistant engineer in May 1855, shortly after the General Post Office extension was added to Meigs' portfolio of projects. His initial responsibilities were primarily with the Capitol Extension and with the Post Office, but on 5 June 1855 Rives traveled with Meigs to visit the aqueduct works, following the Chesapeake & Ohio (C&O) Canal to Great Falls and beyond to the Seneca Creek quarry (Meigs 1855-1860). Meigs assigned Rives a remarkable variety of tasks, extraordinarily quickly, an indication of Meigs' recognition of the 25-year-old Rives' excellence and ability for independent work. Meigs' shorthand journals contain numerous citations to social visits as well as professional interactions (Meigs 1855-1860). Meigs and Rives bonded in a relationship with aspects of mentor-protégé, practitioner-theoretician, and father-son interdependence.

CABIN JOHN BRIDGE – CONCEPTUAL DESIGN

In the winter of 1856, perhaps because of the seasonal slowdown in construction, Meigs and Rives began work on the design of the Cabin John Bridge. The starting point was the conceptual design that Meigs proposed in his report to Congress: "six semi-circular arches of 60 feet span" (Meigs 1853). On 16 January, Meigs wrote: "Today I spent some time with Mr. Rives in looking over his drawing of the Cabin John Bridge arch, investigated by Mèry's Geometrical Construction. We find that the thrust at the keying will be about 90 000 lbs per foot" (Meigs 1855-1860). These results were for a short-span design, which had evolved to one having *five rather than six* arches. Rives performed the structural analyses using Mèry's graphical approach, which he had learned at EPC.

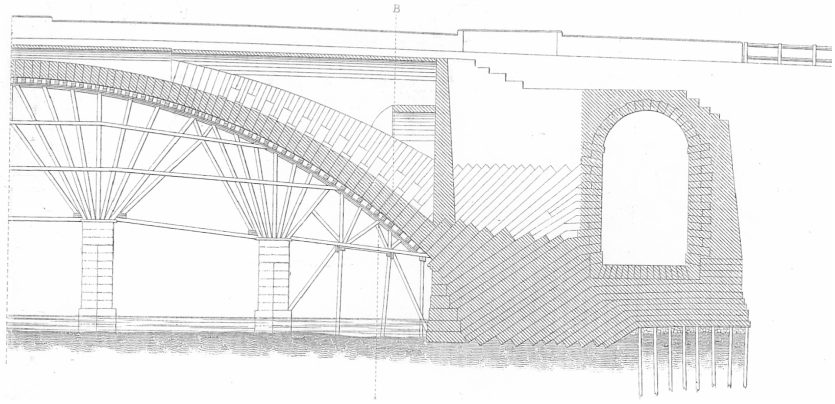

Figure 2: Half section of Grosvenor Bridge (ICE 1842)

In his journal entry for February 7, Meigs mentions the Grosvenor Bridge for the first time: "This is the greatest span now standing, in stone. It is 200 feet. I should very much like to build such a one." Fig. 2 shows a section of the Grosvenor Bridge, which Rives had learned about while studying at EPC. Thomas Harrison prepared the architectural design of the bridge but George Rennie, son of the prominent John Rennie, changed the dimensions of the voussoirs and the abutments' form and dimensions, making it "a typical Rennie structure" (Ruddock 1979, p186). Further, Harrison, then eighty-two years old, asked to be relieved of the responsibility for the construction, which was subsequently awarded to Jesse Hartley, the engineer of the Liverpool docks (Ruddock 1979, p188). The intrados of the Grosvenor Bridge is a circular arc with a radius of curvature of 42.7*m* and an interior angle of 91.2°, giving a span of 61*m*. It has hollow spandrels, but solid spandrel walls. The arch stones are "4 feet deep at the crown, and increase to 6 feet at the springing" (ICE 1842). The contractor, a Mr. Trubshaw, devised an exceptional centering and method of striking. "The centre consists of six ribs in width……. the lagging or covering, which was 4 ½ inches thick, was supported over each rib by a pair of folding wedges, 15 or 16 inches long by 10 or 12 inches broad and tapering about 1 ½ in; for every course of arch-stones in the bridge there were therefore six pairs of striking wedges" (ICE 1842). These wedges allowed a precisely-controlled, slow striking. The contractor's method of striking was to "keep up the crown and let the haunches down," and to perform this soon after the arch was finished, while the lime-based mortar was "yet as it were a paste" (ICE 1842).

In his 9 February journal entry, Meigs notes that he went to the Patent Office to read the article on the Grosvenor Bridge in the ICE Transactions. His "pocket diary" entry for 10 February (a Sunday) states that he met with Rives on that day and the 14 February entry contains the note: "Drew Cabin John Bridge project; a single arch 220' span; 110°; rise 57.255ft." Meigs' journal entry for 18 February contains a sketch of the long-span conceptual design of the CJB and, *in the same entry*, Meigs states that: "Mr. Rives has worked out the bridge thrust, and finds it to be about 700 pounds per square inch." Clearly Meigs and Rives had agreed to do a structural analysis of the long-span conceptual design some days earlier. For Rives to complete Mery's graphical structural analysis, he needed not only the overall geometry but also an estimate of the dead load distribution, which in turn required estimation of the spandrel openings. On 19 February, Meigs recorded: "I worked on the bridge today and made great progress. I arranged the interior of the abutments and spandrils (sic), I think, in a very good way…" On the following day, Meigs noted: "Mr. Rives handed me today the drawing of the discussion of the bridge of 220 feet span. The results are very satisfactory;" Two weeks later, Meigs wrote: "Mr. Rives has finished his drawing of the 5-arch bridge at Cabin John. He has made a very beautiful drawing of it. He now takes up the center of the large arch design for this bridge." Rives and Meigs were apparently leaning toward the record-span design, but as responsible engineers, they decided to estimate costs of the two conceptual designs. On 19 March, Meigs wrote: "Mr. Rives has made a rough estimate of the cost of the two bridges and finds a difference of a few dollars only between them." About a week later, Meigs acknowledged: "I hope to put Rives in charge of the bridge." By the end of March 1856, a decision was probably made to proceed with the detailed design of the 67*m* arch. However, the allocation made in 1856 for the WA had to be used for "existing liabilities and preservation of work already done from injury," requiring the suspension of work on the aqueduct in July 1856.

At this time, however, Congress requested preliminary studies for new bridges over the Potomac River at Washington. Meigs was naturally considered for the work, but he successfully lobbied to have Rives appointed to the job. On 18 November 1856, while Rives was working on his Potomac River bridge study, a fire broke out in the WA Engineering Department and all of Rives' drawings of the CJB were apparently destroyed. At present, the WA Office has no drawings by Rives dating from February or March 1856. William R. Hutton, Rives' colleague on the WA engineering staff, reproduced some of the burned drawings. The WA Office has a copy of the five-arch design (drawing 30.8 4-9) with a pencil note: "Drawing by Mr. Rives destroyed by fire Nov. 18, 1856, from the estimates, W.R.H." Hutton also redrew Rives' graphical analysis of the 67*m* conceptual design; the analysis exists at the WA Office as drawing number 30.12 4-12, dated 11 December 1856.

CABIN JOHN BRIDGE – MODELING, ANALYSIS AND DETAILED DESIGN

Early in 1857, Congress allocated $1 000 000 to continue work on the WA and for a new dome on the Capitol. In March 1857, Meigs commissioned another engineer named Camerhoover to analyze the 67*m* conceptual design for the CJB using an alternate method proposed by Villarceau (1854) (see Heyman 1969). Miegs' journal entry for 13 March 1857 noted that Rives thought "nothing can come out of this, that the 110 degree arc is certainly the arch of equilibrium." Nevertheless, perhaps challenged by Meigs' decision, Rives wrote to his father on 15 March 1857: "The plans I had prepared for Cabin John Bridge having been destroyed by fire, and the reproduction of them, since made, being exceedingly faulty, I have almost my entire work to go over" (Rives 1855-1860). After two weeks, Camerhoover brought his analysis of the arch to Meigs. The Captain admitted that "It differs a good deal from the arc of the circle…. I do not feel confident in the theory [Villarceau's], and I believe I shall stick to the arc of the circle…" In the same entry Meigs further stated: "We have determined to make the voussoirs 6ft deep at the spring and 4ft at the key." Rives and Meigs may simply have decided to use the dimensions of the voussoirs of the Grosvenor arch or, alternatively, Rives performed additional analyses using Mèry's method and concluded that deeper voussoirs were needed near the springing points

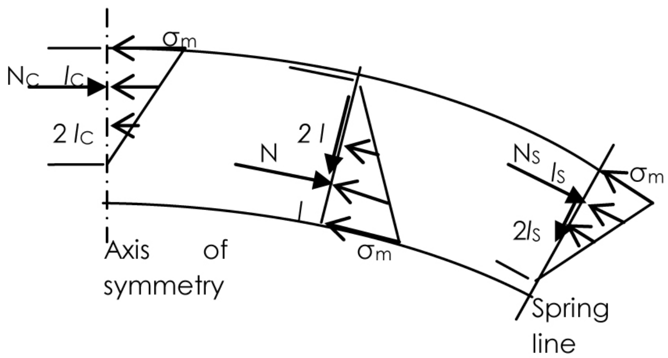

Figure 3: Stresses at arch sections

Mèry's method may be explained as follows. The forces on any section of a planar arch may be defined in terms of a resultant normal force, N, and a shear force acting at a particular point on a cross-section as shown in Fig. 3. The set of points along the arc at which the resultant forces act define a "line of thrust." It is not possible to determine lines of thrust using only equilibrium for masonry arches with no rotational hinges because such arches are statically indeterminate. In his 1840 paper in the *Annales des Ponts et Chaussées*, Mèry proposed a method for determining thrust lines based on three assumptions and a graphical solution of force equilibrium (Mèry 1840). Mèry assumed a symmetric loading condition, which implies that the shear force at midspan is zero, thus eliminating one redundant force. Mèry then suggested assuming the position of the line of thrust at two sections; for example, at the two points defined by l_C and l_S in Fig. 3. With these three assumptions, the resultant normal force at midspan and a complete line of thrust may be determined using only equilibrium; thus the distance l in Fig. 3 is known along the entire arc length. Once a thrust line is determined, Mèry applied two acceptance criteria. The first, which was well-known prior to Mèry, is that the line of thrust must lie between the geometric bounds defined by the extrados and intrados, otherwise one or more rotational hinges would form. The second criterion is that the stone compressive strength must be sufficient to resist the maximum compressive stresses along the arch axis. Navier had previously derived correct formulas for computing maximum normal stresses and further determined that there would be no tensile stresses at a section at which the resultant force was within the "third points" of the section. Mèry did not require that the line of thrust lie within the third points of the section. Rather, he accepted the type of normal stress distribution shown in Fig. 3, which implies limited tensile cracking at any section. From equilibrium of forces normal to a section,

$$N = \sigma_{max}\, b\, (3\, l\,)\, /\, 2 \qquad (1)$$

In which b is the width of the arch and l defines the position of the normal force (and thrust line) from either the extrados or the intrados. Then Mèry's acceptance criterion is that for all sections:

$$\sigma_{allowable}\, b\, l\ \geq 2N/3 \qquad (2)$$

The evident issue regarding Mèry's method is that a complete thrust line is estimated on the basis of its *assumed* location at two sections. In this context, Mèry states:

> There will be, a priori, an infinite number of statically admissible positions for the line of thrust…. and it is only through uncertain assumptions regarding support settlements that one can predict which one will occur; but this search is not necessary…. to assure the strength of the arch. (Mèry 1840)

That is, for a given system of loads, if an equilibrium set of forces is found such that the strength criteria are met without the occurrence of a mechanism, then the capacity of the arch must be greater than the system of loads for which equilibrium is satisfied. Mèry's sophisticated, correct insight is now known as the *lower bound* or *safe* theorem of limit state structural analysis (Gvozdev 1936; Greenberg and Prager 1951).

Rives' structural analysis using Mèry's method guided decisions on overall geometry, the materials to be used, and the sizes of voussoirs, but detailed structural design requires additional engineering judgment and skill. The WA office has copies of the original specifications for the CJB and three drawings dating from 1857 that provide details of the main arch. These drawings are signed or annotated by Rives and then signed-off by Meigs. The specified stone for the main arch was granite from Quincy (near Boston) MA. The decision to order stone from a source approximately 1200*km* away by ship may have been made on the basis of the experience of the general superintendent, Charles T. Curtis, who had previously worked on the Boston Aqueduct (Curtis 1897). WA Office drawing 30.8 4-8 shows Rives detailed an arch with 131 voussoirs in nine distinct sizes, which he dimensioned to an astonishing 0.025*mm* (0.001 in). Rives specified that the joints between voussoirs should be 3.2mm (1/8 inches) and that no other joint should be greater than 6.4mm (¼ inch). Such thin joints imply that the voussoir stones were almost surely finished on a *rubbing bed,* as done for some of the stonework for the Capitol. Rives specified natural hydraulic cement rather than lime for both the concrete foundations and the mortar.

A prominent feature of the design is the stepped radial *rubble backing arch*. It is made of sandstone from the Seneca quarry, approximately 22*km* upstream from the bridge site. This radial backing arch is similar to the radial placement of masonry above the main arch of the Grosvenor Bridge, a common Rennie feature, although usually not expressed on the exterior of the spandrel wall (Ruddock 1979). Its presumed purpose is to increase strength or *stability*, although its width is only a fraction of the 6.2*m* width of the principal arch. One practical advantage of the backing arch is that its stepped extrados avoids "sharp points in the horizontal courses" of the spandrel walls (Hutton 1899). As in the Grosvenor Bridge, the external spandrel walls are solid, hiding the spandrel arches. The spandrel walls are vertical but their extensions in the abutment areas have a slight batter of 1 in 20. Ruddock (1979) notes that battered wing walls were standard construction for bridges in Scotland after 1800.

CABIN JOHN BRIDGE – CONSTRUCTION

On 14 March 1857 Meigs created a new division of the WA, only about .8km long, centered on the CJB, and named Rives, at age 27, division engineer in charge of construction of the bridge. Rives had the immediate tasks of re-creating the drawings lost in the fire, making detailed working drawings, and developing construction techniques. About three weeks later, Meigs wrote: "Got home at 12 ½ AM and found a couple of drawings of the center of Cabin John Bridge by Rives, which he left for my signature in order to set the carpenters to work to make patterns" (Meigs 1855-1860). On April 21, Rives wrote to his brother: "The work at my big bridge is already underway. Most of the drawings are prepared, and my center, of which I am very proud, is underway" (Rives 1855-1860). Rives' center is shown on a colored drawing labeled *scaffolding* in the WA Office. The drawing was completed much later, probably as a "presentation piece," on 30 November 1859. It shows that four-or-five stones formed the 6.2*m* width of the arch. Therefore Rives designed a center consisting of four plane frames with fanned timbers to form the circular arc. Rives used one centrally located steam hoist with a pulley system to lift the voussoir stones to two high-level platforms. The stones were then placed in position using three traveling platforms with winches. Rives used *wire* ropes, which were supplied by John A. Roebling's Sons of Trenton, NJ. Fig. 4 shows the critical details that allowed adjustments as the center deformed under load, and that subsequently facilitated striking the center. Rives used four pairs of wedges, one pair over each frame, at every voussoir location. This design is obviously reminiscent of that used for the Grosvenor Bridge. Rives wrote to his mother on 23 July 1857 that: "the center for my grand arch is finished" (Rives 1855-1860). The Quincy granite stones came by ship to the Georgetown docks and then by C&O canal to within a short distance of the bridge. To transport the stones to the actual site Rives dammed Cabin John Creek to create a small pond and constructed a lock to connect the pond to the canal. He wrote to his sister Amelie on 12 October 1857 that: "I have been occupied this summer principally in constructing a lateral canal to the Chesapeake and Ohio Canal and had the good fortune to open it successfully on last Wednesday. The water had not been in more than an hour when Capt. Meigs and Gov. Floyd, Sec. of War, rode up. Both seemed pleased with the work especially the Capt. who was kind enough to compliment me most warmly to the Sec. of War and before 'tout le monde.'" Rives safely placed nearly 600 large granite stones during the summer of 1858 and "keyed" the main granite arch on 4 December 1858. Rives' pride in his accomplishment is evident in the letter he wrote to his brother on 6 December 1858: "the Grand Arch was keyed on Saturday the 4th… at 2 o'clock" (Rives 1855-1860).

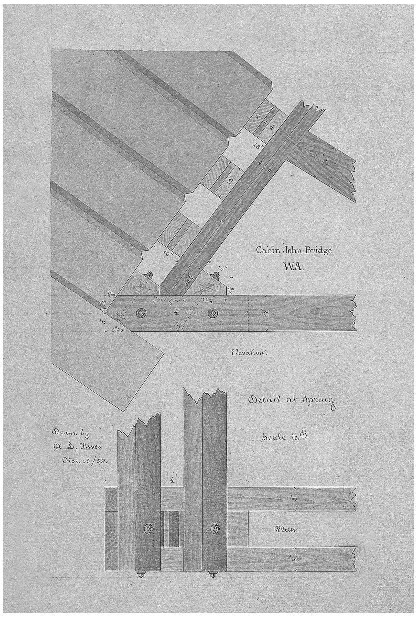

Figure 4: Centering detail showing wedges for striking (from WA Office drawing)

The successful keying of the main arch was followed by a four-and-a-half year period of sporadic construction due to funding interruptions, changes in leadership, and civil strife that changed the lives of both Rives and Meigs. These conditions delayed the completion of the WA and its permanent operation until July 1864. In 1860 Meigs became a target of the Secretary of War, John B. Floyd, perversely because of Meigs' zealously ethical management of congressional appropriations. In July 1860 Floyd appointed Capt. Henry H. W. Benham as chief engineer of the WA and in October banished Meigs to Fort Jefferson, on Garden Key of the Dry Tortugas, about 110*km* west of Key West, Florida (East 1939). In turn, Secretary Floyd himself was replaced and Meigs was ordered back to Washington. On 21 February, 1861 Meigs was reappointed chief engineer with approximately $321 000 of remaining appropriations. A last brief period of professional collaboration between Meigs and Rives ensued until the start of the Civil War. On 17 April 1861 Virginia seceded from the Union and Rives resigned from the WA to become an engineer with the Confederate States of America, a decision that caused Meigs to shun Rives. On 15 May 1861 Meigs was promoted to brigadier general, serving with distinction as the army's quartermaster general until 1882. Meigs' formal responsibility for the WA ended on 18 June 1862 when Congress transferred all jurisdiction for the WA from the War Department to the Department of the Interior. The Department of the Interior appointed William R. Hutton chief engineer in 1862-63 and he was followed by Silas Seymour from 1863-64. The WA and the CJB were essentially completed under their leadership.

CONCLUSIONS

Alfred L. Rives performed brilliantly at EPC; he was apparently the first American graduate of the Ecole following three years of study. On graduation, he was presented with 150 volumes of technical books, including the entire collection of the *Annales des Ponts et Chaussées*. He had studied Mèry's method of graphical analysis of arches and was familiar with the Grosvenor Bridge. Rives began his work on the CJB in January 1856. Meigs had originally proposed a six-arch viaduct in 1853, but Rives initially completed an analysis and design of a five-arch bridge. A 67*m* single-span arch would probably not have been even considered for the CJB without the technical knowledge that Rives shared with Meigs and the entire engineering staff of the WA. Rives probably informed Meigs of the Grosvenor Bridge and trained the engineering staff in the use of Mèry's method. The Grosvenor Bridge was certainly the model for the long-span conceptual design of the CJB. The two bridges have almost identical voussoir sizes and both utilize radial masonry to form *backing arches*.

Meigs' pocket diary entry for 14 February 1856 gives the geometry of a circular arc that was used for the CJB. Calculating such geometry is a simple task that does not equate with structural design of an arch bridge. Meigs' shorthand journal entry for 18 February 1856 contains a sketch of the CJB, but the same entry also contains Rives' results from a structural analysis of the long-span concept. A structural analysis requires not only the geometry, but also an estimate of the distribution of weight, which Rives must have done before that day. William R. Hutton, who worked on the WA in the winter of 1855-1856, explicitly gave Rives credit for the long-span concept: "The present single span of 220 ft was suggested by Mr. Alfred L. Rives…" (Hutton 1899). Moreover, in 1857, Meigs commissioned another engineer named Camerhoover to check the long-span design, a very unlikely decision if the concept was indeed Meigs' own.

Beyond the long-span conceptual design, there is no doubt that Rives did the structural analysis and detailed design of the main arch. This is verified by existing documents and drawings, specifically the graphical analysis sheet and the drawing of the details of the arch stones. Without doubt, Rives designed the center for the CJB, using the center for the Grosvenor Bridge as a precedent. Rives devised the construction techniques and was division engineer for the CJB from 1857 to the "keying" of the main arch on 4 December 1858.

On the basis of existing documents and drawings, and with the understanding that *structural* design consists of conceptual design, structural analysis, and detailed design, it can be concluded that the Cabin John Bridge was not only built by, but also designed by Alfred L. Rives, C.E., *ancien eleve externe* of the École des Ponts et Chaussées, the top graduate of the class of 1854.

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ACKNOWLEDGEMENTS

The authors gratefully acknowledge Patricia Gamby and Thomas Jacobus of the Washington Aqueduct Office; Dean Herrin and Christopher Marston of the National Park Service; Adel Saada; G. Saquet of EPC; staff at the Library of Congress, National Archives, Office of the Architect of the Capitol, and library staff at the University of Virginia and at Duke University.