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September 16, 2014

Julie Bolthouse - Fauquier County Field Officer
Piedmont Environmental Council
45 Horner Street
Warrenton, VA 20186

RE: Structural Review of the Historic Waterloo Bridge, Rte. 613 Over the Rappahannock River, Fauquier & Culpeper Counties, Virginia

Dear Ms. Bolthouse:

Please find the enclosed structural review prepared by The Schiffer Group, Inc. ("SGI") as the culmination of our field visit to the bridge this summer along with Workin' Bridges and Bach Steel.

Thank you for including us in your efforts to explore whether this significant structure can be preserved. As you will find as you dive into the report, it is our opinion that restoration/preservation of the bridge is a viable option.

Should you find the need for additional assistance (i.e.: testing, structural modelling and analysis, etc.) in the future on this or other projects, please do not hesitate to contact us. Please also keep us informed as you continue forward on this project; we are very interested to hear what the final outcome for this bridge will be.

Once again, we appreciate having had the opportunity to work with you on this exciting project – we wish you the best as you proceed forward.

Respectfully Submitted by,

THE SCHIFFER GROUP, INC.

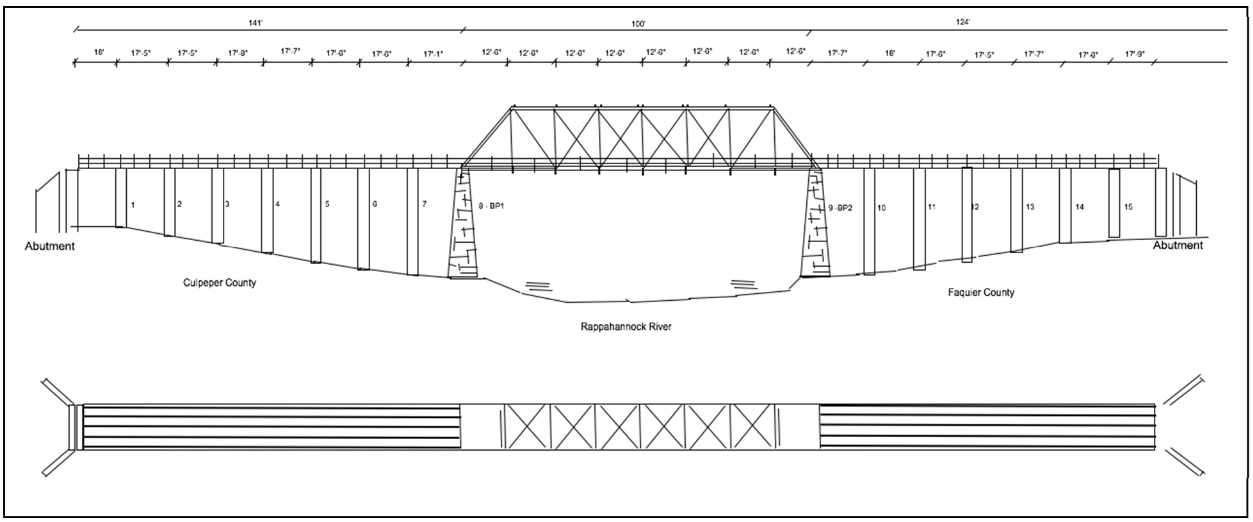
James B. Schiffer, P.E.
Principal

Encl: Structural Report (33 pgs.)

1308001-005 Waterloo CltrR02.docx

Piedmont Environmental Council

STRUCTURAL REVIEW OF THE HISTORIC WATERLOO BRIDGE
Rte. 613 Over the Rappahannock River
Fauquier & Culpeper Counties, Virginia



Prepared 2014 By:

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EXECUTIVE SUMMARY

As stated by the Piedmont Environmental Council (PEC) and others, we agree that the Waterloo Bridge is a valuable piece of the history of Culpeper and Fauquier Counties and if feasible, that this historic bridge should be rehabilitated and remain open for vehicle traffic.

It is with this charge that the Workin' Bridges team was engaged to review the condition of the bridge and approaches in order to:

- Assess the condition of the structure (see photos, Appendix A)
- Review available structural documentation
- Prepare preliminary budget estimates for bridge restoration to be considered during evaluation of the options to reopen Route 613 (Waterloo Road) – whether that will be for vehicular, bicycle, or pedestrian traffic.

As a result of this study, a summary of the findings are as follows:

1) It has been reported that prior to closure the bridge carried a daily average of 670-840 vehicles.
2) Beginning in 2007 it was suggested that the bridge be scheduled in the Virginia Department of Transportation (VDOT) 6-Year Plan for replacement.
3) For the last ten years minimal maintenance has occurred; this is consistent with the recommendation for scheduled replacement.
4) The last notable maintenance items to the structure were:
    a. Superstructure painting over existing paint (2004)
    b. Occasional timber deck plank and curb replacements (Various yrs)
    c. Shimming of truss bearings (2007)
    d. Repair of the north approach rail on the upstream side (2007, 2008)
    e. Replaced diagonal L3-U4 with cable/turnbuckle assembly (2009)

   f. Isolated beam ends with significant section loss retrofitted with channels and angles (2011)

   g. Isolated tuckpointing at masonry piers (2013)

5) No reductions in load rating (3 ton) were made prior to the January 15, 2014 closure of the bridge.

6) The bridge was closed January 15, 2014 when it was "…determined that the deterioration was too severe to continue to allow traffic to use the bridge", per VDOT spokesman interviewed by Fauquier Now.

7) During the Workin' Bridges team's site survey of conditions conducted on June 27th and 28th this year we did not observe conditions differing substantially from the inspections carried out over the last ten years.

Based on these findings and the information that follows here, it is our opinion that this bridge is a viable candidate for restoration to (limited) vehicular use. We have therefore prepared a recommended restoration cost estimate (see end of this report) that may be used during the review of optimal solutions to the closure by VDOT and the stakeholders.

DESCRIPTION

As excerpted from the Historic Architectural & Engineering Record HAER-VA-112 - Waterloo Bridge report, the Waterloo Bridge is a bridge whose distinctive iron and steel Pratt through-truss dates to the late 19th century, spans the Rappahannock River and links Waterloo and Old Bridge roads in Culpeper County to Jeffersonton Road in Fauquier County.

Details regarding the history, type, and size of bridge, members and spans is contained within the Historic Architectural & Engineering Record HAER-VA-112 - Waterloo Bridge, see Appendix B.

The Conclusions & Estimates section at the end of this report was prepared based on the information contained in this HAER-VA-112, our on-site observations, and the following Research of Period Structures section that follows here.

RESEARCH OF PERIOD STRUCTURES

Materials

Metallurgical tests of the framing elements were not taken, however we are fairly certain the framing systems consist of a combination of wrought iron and structural steel elements. The reasons being:

Year of Construction (1878 (per VTRC 98-R3)) - Steel beams were introduced for general use in 1884[1,2] therefore the availability of steel would have been somewhat limited in 1878. Prior to the introduction of steel, the material of choice was either a form of cast iron or wrought iron. Cast iron, as the name implies, was cast into the desired shape. Wrought iron was mechanically worked and mechanically formed into the desired shape. Cast iron tended to be strong in compression, however lacked in ductility and was weak in tension. Early iron bridges were often constructed of cast iron compression members and wrought iron tension members in the shape of bars. Cast iron use in bridges was discontinued circa 1880[3]. Rolled wrought iron shapes (channels and standard beam sections) were introduced in 1861[4] and remained in use until the end of the century, at which time steel was in widespread use.

Observations - Both steel and wrought iron structural elements are rolled, which leads to similar shapes. Wrought iron members are also typically built up by riveting together iron plates or small rolled shapes[5]. Delaminated edges resulting from mechanical working can sometimes be observed in wrought iron elements. We did observe some delamination of one of the compression flange cover plates. The built up truss compression elements and the delaminated plate are indications that the truss elements are wrought iron.

We have also observed on bridges of this era that transverse beam elements were often made of rolled steel. A manufacturer's stamp which is characteristic of rolled steel is typically used to determine whether larger

[1] Alexander Newman, p.106
[2] Llewellyn Edwards
[3] Ibid.
[4] Ibid.
[5] Alexander Newman, p.107

beams were made of steel and not iron. We did not have access to examine the floor beams directly but will assume that they were made of steel at this time.

Known Use - The use of wrought iron elements in pre turn-of-the-century bridge construction is well documented. Some aspects regarding field and laboratory testing of similar bridge elements is referenced later in this report.

It is our opinion elements that form the truss portion of the bridge are of wrought iron construction and that the larger transverse deck beams and beams in the approach span (later construction, 1918-19) are of steel.

Material Strengths and Allowable Stresses:

Published allowable design stresses for wrought iron formed between 1850 and 1900 generally range from 10,000 psi to 14,000 psi[6,7,8]. Data was reviewed from two studies that evaluated strength properties of wrought iron taken from same era truss bridges. A national study of wrought iron in historic bridges[9] resulted in a minimum tested yield strength of 32 ksi and a minimum tested failure strength of 48 ksi. We typically target an allowable stress value for wrought iron of 12,000 psi, which aligns with period design stresses. Tests on similar structures also indicates that a selected design stress of 12,000 psi would provide a factor of safety of 2.6 against yield and 4.0 against failure, which exceed factors of safety per current design standards.

Published allowable stresses for early steel range from 12,500 psi to 16,000 psi[10] depending on the application. We typically target an allowable value of 12,500 psi as published for bridge use. This selected allowable stress provides for a factor of safety against material failure of 4.8.

The allowable stresses as noted above are based on design approaches that would have prevailed at the time the bridge was constructed. Current design allows for higher allowable stresses up to 55% of yield, which results in 17,600

6 Alexander Newman, page 105.
7 Robert Gordon, page 395.
8 Herbert Ferris, page 5.
9 Robert Gordon, page 395.
10 Herbert Ferris, page 5.

psi for a yield stress of 32,000 psi. The difference in allowables stems from an increased understanding of loads, materials and behavior of materials that has occurred through the years. Although we will analyze structures in respect to period design approaches, we usually also consider current allowables in evaluating recommendation options.

Timber design values, more so than other standard construction materials, are difficult to determine. Timber is often given general classifications or grades based on visual observation of the wood. Allowable stresses could vary considerably depending on an assigned classification. Lumber purchased today have classifications noted on individual pieces. When working with older structures such as this, particularly roughhewn timbers, the grade of the timber is not known, nor is it feasible to determine capacity without strength testing of a sufficient number of elements to form statistical conclusions. We generally use a lower grade of mixed southern pine when the grade is not known. Our observations of the timber deck planks and are relatively clear and true, which would correspond to a higher grade of lumber, however, due to age we typically use the lowest grade of mixed southern pine per AASHTO tables, which results in a basic bending allowable stress of 875 psi. The allowable stress can be increased 15% due to the use of distributed loading, and increased 15% due to relatively short live load duration, resulting in an adjusted target allowable of 1160 psi.

Fatigue Strength:

Fatigue is the loss of capacity of an element due to cyclic stresses. This loss of capacity means that an element could fail well before it is stressed to the theoretical failure strength. The general approach to develop data for fatigue evaluation is to cycle through a select stress range until the material fails. This process is repeated multiple times until a correlation is developed between the applied stress range and the number of cycles to failure. The fatigue limit is the maximum stress which can be applied repeatedly without causing failure.[11]

The reason that fatigue is discussed in this report is that a structure that is 129 years old has cycled though loading many times in its lifetime. Applying an Estimated Average Daily Traffic as report (we would use the high 840 ADT) will produce well over 10,000,000 occurrences of traffic passing over the bridge.

[11] Carl Keyser, page 63.

This number of loading occurrences is well into the range of those that could detrimentally impact the capacity of a structure.

To incorporate the impact of fatigue as it relates to the condition analysis, we recommend consulting three sources; steel fatigue limits as described by AASHTO, a study titled "The Evaluation of Wrought Iron for Continued Service in Historic Bridges" by Robert Gordon and a study performed on Iowa bridges by W.W Sanders titled "Ultimate Load Behavior of Full-Scale Truss Behavior".

In general, wrought iron is perceived to be superior to steel in resisting corrosion and fatigue conditions.[12,13] Adherence to AASHTO steel requirements would limit the maximum allowable stress range to 24 ksi. This form of truss dictates that elements are either in tension or compression without variation, which then dictates a maximum applicable stress of 24 ksi. A fatigue stress of 24 ksi indicates that if the maximum stress does not exceed 24 ksi, the number of cycles will have little impact on capacity.

The Gordon study concluded that "The wrought iron used in historic bridges, if initially of good quality, can continue to give its original service indefinitely if protected from corrosion and the bridge's design load limitations are respected."[14]

Many fatigue studies have been performed. These tests are typically made on elements that had already been in use approximately +75 years at the time of the study. These tests typically show that there was considerable life remaining in the tested elements.

It is our opinion that an applied stress limitation of approximately 12,000 psi for wrought iron and 12,500 psi for steel will allow for continued service of the bridge.

Conclusions:

While full analysis of the bridge’s and approaches’ remaining capacity is outside the scope of our contract, we note that it is due to this research and our

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[12] T.B. Jefferson, page 61
[13] *Wrought Iron*, page 4.
[14] Robert Gordon, page 398

experience with similar structures, that we conclude that restoration is a viable option. We therefore make the following recommendations.

RECOMMENDATIONS & BUDGETS

Recommendations:

In order to make long lasting improvements that are secure, we recommend considering the following scenario for restoration:

1) Consider full dismantlement. This will allow:
    a. Final removal of the lead based paints
    b. Thorough (bare metal) examination of members requiring replacement and/or repair
    c. Suitable work locations to safely, economically, and efficiently make these modifications.
2) Install rails and guardrails that will satisfy low speed vehicular loading.
3) Improve the northside grading to divert drainage from the piers and bents.
4) Remove the trees at the southside pier.
5) Retain ownership of the bridge by VDOT so that state resources and qualified contractor selection can remain in place.
6) Retain the historic use – limited vehicular one-lane traffic.
7) Restore the bridge while maintaining the historic methods of construction (both material and methods (hot riveting, etc.)).

In order to evaluate the feasibility of following these recommendations we offer the recommended budget that follows.

Budget:

Preliminary Design Estimate Of Probable Construction Costs

ITEM	ITEM DESCRIPTION	Qty	Unit	UNIT PRICE	TOTAL AMOUNT
1	General Conditions / Mobilization (3% Max.)	1	L/S	$33,675	$33,675
2	Demolition / Removal of Approach Superstructures	1	L/S	$32,160	$ 32,160
3	Grade North Approach / Drainage Improvements	3	STA	$15,000	$ 45,000
4	Prep. Crane Location(s), Crane Rental	1	L/S	$ 101,600	$ 101,600
5	Removal of Bridge Decks	1	L/S	$28,400	$ 28,400
6	Dismantlement of Trusses	1	L/S	$20,580	$ 20,580
7	Blast / Paint / Haz. Disposal	1	L/S	$ 150,000	$ 150,000
8	Repair Bents, Piers, Abutments	1	L/S	$ 230,000	$ 230,000
9	Repair trusses (inclined endpost, diagonal, bearings,etc.)	1	L/S	$15,800	$ 15,800
10	Repair Braces	8	Each	$3,000	$ 24,000
11	Replace Floor Beams	8	Each	$8,960	$ 71,680
12	Replace Bearings	2	Each	$4,200	$ 8,400
13	Reassemble / Re-erect Trusses	1	L/S	$17,640	$ 17,640
14	Erect new approach steel outriggers and rails	30	Each	$1,176	$ 35,280
15	Erect new approach stringers	40	Each	$2,125	$ 85,000
16	Re-erect pipe rails	26	Each	$65.00	$ 1,690
17	New Rail Cables	1	L/S	$42,600	$ 42,600
18	New Decking	1	L/S	$ 107,680	$ 107,680
19	Repair paving, strategic widenings	1	L/S	$35,000	$ 35,000

20	Signalization (one-lane)	1	L/S	$20,000	$ 20,000
21	Install height restrictions (7.5' clearance bars)	1	L/S	$10,000	$ 10,000
22	Restoration	1	Allow	$10,000	$ 10,000
23	Permits / Sampling	1	Allow	$10,000	$ 10,000
24	ROW / Grading Easements	1	Allow	$20,000	$ 20,000
25					
26					
27					
	Subtotal				$ 1,156,200
	Undeveloped Details	20%		$ 231,200	$ 231,200
	Subtotal (Construction Costs)				$ 1,387,400
	Final Design and Construction Engineering	20%		$ 277,500	$ 277,500
	Subtotal (Design & Construction Costs)				$ 1,664,900
	Construction Contingencies	10%		$ 138,700	$ 138,700
	Total *Preliminary* Engineering Opinion of Probable Project Cost				**$ 1,803,600**

FOOTNOTES & BIBLIOGRAPHY

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Sanders, W.W., Jr., H.A. Elleby, F.W. Klaiber, *Ultimate Load Behavior of Full- Scale Highway Truss Bridges*, Ames, Iowa: Engineering Research Institute, Iowa State University, September 1975.

Wrought Iron: Characteristics, Uses and Problems, U.S. General Services Administration, Historic Preservation Technical Procedures.

Appendix A

Structure Photos

Appendix A

Top chord connection and portal bracing detail. Note pin for lateral bracing extending through the top chord batten plates (an unusual design feature of this bridge), denoted by red arrows. This detail is found at all panel points.

Expansion bearing (roller nest) and bottom chord connection at end post. Note minor buildup of debris.

Detail of bottom chord connection with added cable and broken counter (denoted by red arrow).

Top chord connection detail.

Overview of floor beams, deck stringers, and lateral bracing under the deck of the truss span.

Isolated area of damage to top chord.

Existing welded plate repairs to end post.

Vertical member detail showing rolled tee and riveted lacing. Note the use of angled ends on the lacing bars as opposed to rounded ends most commonly found on truss bridges.

Overview of concrete bent.

Detail of approach span stringer (typical).

Typical example of spalling on a concrete bent.

Overview of stone abutment.

Appendix B

HAER Report

WATERLOO BRIDGE
(Bridge No. 6906)
Spanning the Rappahannock River at Virginia Route 613
Waterloo
Culpeper County
Virginia

HAER No. VA-112

HAER
VA
24-WATLO,
1-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
U.S. Custom House
200 Chestnut Street
Philadelphia, PA 19106

HAER
VA
24-WATLO,
1-

HISTORIC AMERICAN ENGINEERING RECORD
WATERLOO BRIDGE
(BRIDGE NO. 6906)

HAER No. VA-112

LOCATION: State Route 613 over the Rappahannock River, Waterloo, Fauquier and Culpeper counties, Virginia. USGS Jeffersonton, VA Quadrangle, Universal Transverse Mercator Coordinates: 18.247260.4286810

DATE OF CONSTRUCTION: 1885, 1918-1919

BUILDER: Virginia Bridge & Iron Company, Roanoke, Virginia

PRESENT OWNER: Virginia Department of Transportation

SIGNIFICANCE: The Waterloo Bridge presents representative examples of two types of bridge technology. It features a pin-connected iron and steel Pratt through truss typical of late nineteenth century factory-manufactured bridges, and a series of early twentieth century steel beam deck spans supported by reinforced concrete piers.

PROJECT INFORMATION: The Waterloo Bridge was recorded in 1993-1994 by the Cultural Resource Group of Louis Berger & Associates, Inc., Richmond, Virginia, for the Virginia Department of Transportation (VDOT). The recordation was undertaken pursuant to provisions of a Programmatic Memorandum of Agreement (Draft) among the Federal Highway Administration, VDOT, the Virginia SHPO, and the Advisory Council on Historic Preservation concerning management of historic metal truss bridges in Virginia. Project personnel included Richard M. Casella, Architectural Historian, and Rob Tucher, Photographer.

DESCRIPTION

The Waterloo Bridge (VDOT Bridge No. 6906) consists of a pin-connected metal through truss main span, believed to have been built in 1885, and fifteen steel beam deck spans erected in 1918-1919. The bridge carries a single lane of Virginia State Route 613 in a northeast-southwest direction over the Rappahannock River, about 400' south of the confluence with Carter's Run, a tributary stream (Figure 1). The bridge connects Fauquier County on the east side with Culpeper County on the west side. At the point of the bridge, the riverbed is approximately 80' wide, with an east floodplain approximately 120' in width and a west floodplain approximately 140' in width. The maximum depth of the river is typically 1' in midsummer. The immediate area around the bridge is heavily wooded, bordered by open farmlands and widely spaced residences. The east bank of the river increases grade rapidly as it climbs the southern foot of Piney Mountain. To the north of the bridge, bordering Carter's Run, are expansive flat farm pastures and fields. To the west and south of the bridge are rolling farmlands and woodlands.

Waterloo Bridge has an overall length of 367' 1", consisting of the truss span, 100' long; the east approach of seven deck spans, with an overall length of 124' 8"; and the west approach of eight deck spans, with an overall length of 142' 5".

The center structure is an iron and steel Pratt through truss 100' in length, 15' 8" in height, and 13' in width, with eight panels each 12' 6" wide. The truss spans the riverbed at a height of 28' (Figure 2).

The riveted bar-lattice posts are 8" x 5" overall, made up of two rolled Tee's, 5" x 2-3/8", connected by 1-1/4" x 10" single bar-lattice. Top chords and inclined end posts are riveted box sections, 12" x 6-5/8" overall, built with 3/8" top plate, 6" x 1-3/4" side channels, and 4" x 12" x 5/16" stay plates spaced 4' 4" on center. Bottom chords consist of two loop-welded eye-bars, 3" x 3/4", with the exception of the chords connecting the end post and the first post, which are 1-3/16" square (Figure 3).

The diagonals consist of two 7/8" diameter rods with loop-welded eyes located in all but the end panels. Single counters are located in the four center panels and consist of 7/8" diameter loop-welded eye-bars with sleeve nuts. Hip verticals consist of two 7/8" diameter loop-welded eye-bars. Posts, chords, and diagonals are connected with 1-3/4" pins.

Portal struts are lattice girders with Tee flanges and bar-lattice webs. The bottom flange of the portal strut curves downward and is bolted to the end post to provide integral portal bracing. Top lateral struts are 6" rolled I-beams, pin-connected to each post. Sway braces are Tee's, attached with bolts. Top lateral bracing consists of two 7/8" diameter loop-welded eye-bars.

The 11' wide roadway is edged with 6" x 6" wood curbing raised 6" off the flooring with wood blocking spaced approximately 4' on center. The 4" x 12" pressure-treated wood flooring is attached to the steel stringers with carriage bolts and steel deck clips. The floor is carried by five 10" x 4" I-beam stringers, spaced 2' 9" on center. The floor beams are also 10" x 4" I-beams, hung from the bottom chord pins at each post by 1" square U-bolts and hex nuts. There are no end floor beams. Bottom lateral bracing consists of two 7/8" rods with both ends threaded, connected to the ends of the floor beams with skewback brackets. The truss rides on four metal bearings, each approximately 13" square, made up with plate and six 1-1/2" rollers, spaced 2" on center.

The truss rests on stone piers constructed of random rubble and ashlar masonry, erected in 1885 with later additions to increase their height. The piers, which stand 21' above the surrounding ground, are battered and measure approximately 16' x 5' at the top and 21' x 8' at the base.

The east and west approaches are steel beam deck bridges of identical construction. The east approach has six spans measuring 17' 9" and one span measuring 18' 2", at an average height of 17' above the floodplain. The west approach has seven spans measuring 17' 9" and one span measuring 18' 2", at an average height of 19' above the floodplain. The fifteen deck spans consist of five 9" x 4-1/2" steel I-section stringers spaced 2' 9" on center. The flooring is as previously described, and the stringers rest directly on the concrete piers.

The steel deck sections of the bridge rest on open reinforced concrete piers and reinforced concrete abutments. These structures were built by the Virginia Bridge & Iron Company in 1918 and 1919 (Fauquier County Board of Supervisors 1918:345-348, 1919:398).

The open reinforced concrete piers consist of two square columns supporting a square pier cap. The junction of the column and cap is reinforced with a diagonal gusset at the inside corners, creating a polygonal portal. This feature was built into the form work, and each pier was cast in place as a single unified structure. The piers are 14' x 2' and vary in height with the terrain between 13' and 20'. There are a total of thirteen piers, six supporting the east approach and seven supporting the west approach.

The end spans of the approaches rest on reinforced concrete beveled wing abutments. The east abutment was cast in place on top of an earlier rubble masonry abutment.

The bridge railings consist of two horizonal rows of 2" steel pipe, at heights of 28" and 46", attached with U-bolts to vertical 2-1/4" angles, spaced approximately 3' on center.

HISTORICAL INFORMATION

Background

Waterloo Bridge and the settlement around it can trace their origins to the mid-eighteenth century when farms were established along the fertile Rappahannock River Valley. The broad section of the valley, formed at the confluence with Carter's Run, offered large tracts of relatively flat arable land as well as waterpower. Glasgow merchants controlled the tobacco trade in the Piedmont region of Virginia, and they encouraged the building of roads and stores for the purchase of tobacco and the sale of merchandise. About 1749, the Lower Dumfries Road was created to connect the mouth of Carter's Run and the settlement there, known as Waterloo, with Fauquier and Allentown Pike and Dumfries Road, thereby forming a triple junction at the Fauquier County Courthouse (Groome 1927:202).

As the interior of Virginia became more thickly settled, villages grew up along the Rappahannock at points which offered fords or falls. As early as 1794, the merchants of Fredericksburg recognized the potential benefits of opening navigation on the Rappahannock River. A canal that utilized the river could connect the markets at Fredericksburg to the farms and forests of four counties: Fauquier, Culpeper, Loudoun, and Rappahannock. An attempt in that year to capitalize a canal company failed, as would repeated attempts made every few years until 1829, when construction finally began. Four locks were constructed by 1831, opening a short section of the lower Rappahannock just above Fredericksburg, but floods and financing problems repeatedly stalled the project. Waterloo was planned as the northern terminus of the canal, and much of the development of the village was undoubtedly based on the commerce that the canal would surely bring (Callaham 1967:17).

In 1848, the Virginia legislature, convinced of the value of the project, granted $100,000 to complete the canal. Work immediately progressed to Weatley's Mill just north of Kelly's Ford, about fifteen miles south of Waterloo. The northern and final section of the canal, from Porter's Locks to Waterloo, covered a distance of three miles. The contractor for this section failed to complete the project due to heavy rains and the inability to pay his workers. With a vested interest in seeing the project finished, Waterloo resident and builder John Spillman Armstrong and his brother-in-law Joe Settle stepped forward and were awarded the contract (Fauquier County Bicentennial Committee 1959:110; Scheel 1982:148).

John Spillman Armstrong was one of the early residents of Waterloo and bought a 400-acre farm on the Culpeper side of the river sometime in the late 1830s or early 1840s. Armstrong had worked as an operator of a sawmill and gristmill and became known in the area as an accomplished builder. Armstrong and Settle finished the canal ahead of schedule and each earned $10,000 plus a $2,500 bonus (Works Progress Administration 1978:299).

Upon its completion in 1849, the canal route stretched fifty-eight miles from Waterloo to Fredericksburg and consisted of fourteen miles of dug canal, forty-four locks, and twenty dams. Canal barges transported flour, timber, and farm products down the canal and brought lump plaster back to be ground for fertilizer (Callaham 1967:34; Works Progress Administration 1978:302).

During its construction and for the short time it operated, the canal brought prosperity to Waterloo. With the money he made from finishing the canal, John Armstrong bought the neighboring 800-acre Dr. Rose Farm. He laid out a town with streets and lots on his new land and put up a store and two large warehouses which he rented to Messrs. Settle and Knox. Armstrong also bought a large, steam-powered circular sawmill in Baltimore and had it brought up from Fredericksburg by eight oxen. The sawmill was the first of its kind in the area and attracted wide attention. Armstrong supplied the lumber for the construction of houses, stores, and factories, which was proceeding at a rapid pace on both sides of the river (Fauquier County Bicentennial Committee 1959:113, 114; Works Progress Administration 1978:299).

On the Fauquier side of the river, a longtime resident and large land owner named Keith laid out his property into what he called the Factory Lot. By 1852, the Factory Lot consisted of three stores, a large woolen mill, a canal boat shop, a blacksmith shop, and several warehouses. The early plans of Armstrong and Keith are not believed to be extant, nor is the precise number of houses in the community on record, but based on the commercial activities at least several dozen families must have lived in the village (Fauquier County Bicentennial Committee 1959:115; Works Progress Administration 1978:299).

In 1852, the Orange and Alexandria Railway and the Manassas Gap Railway began operation in the region and sent a shock wave through the Rappahannock Valley. The railroads, compared to the canals, could move goods at half the cost, in a fraction of the time, regardless of ice or floods. The death blow dealt by the railroads was swift and sure: the canal ceased operation in 1853, never having returned a profit to its investors. The canal had cost $372,000 and was sold in 1868 for $1,500 (Fauquier County Bicentennial Committee 1959:112).

In 1853, following the financial collapse of the canal, Waterloo's first known bridge, a 200' wooden structure, was constructed. Aside from the obvious benefits of uniting the east and west parts of the village, the bridge stimulated cross-county road traffic and further established Waterloo as a commercial center (Scheel 1982:137).

Exactly what impact the loss of the canal had on Waterloo in the ensuing eight years is unclear and perhaps irrelevant in light of the events that befell the village with the onset of the Civil War. In 1861, in one of the early skirmishes of the war in Virginia, General Shields was defeated by Stonewall Jackson and passed through Waterloo on his return to Washington. Edward Armstrong, John's son, was 14 years old at the time and remembered watching from a hilltop as Shields burned the factory buildings and warehouses. Miller's Woolen factory, owned by Middleton Miller and Brent Green, had been manufacturing cloth for Confederate uniforms. Angered by the destruction of his village, and against his fathers strict orders, Edward ran away and joined the Confederate army. Several months later, after the first battle of Manassas, General Beauregard passed through Waterloo in his fall back to Richmond. To slow any advance of Union forces, he burned the bridge (Fauquier County Bicentennial Committee 1959:117; Scheel 1982:136, 137).

The following June, General John Pope was given command of about 38,000 troops in Virginia, with orders to consolidate the corps of McDowell, Fremont, and Banks and assist McClellan in his advance on Richmond. His orders called for him to hold a line along the Rappahannock River to prevent an advance on Washington by General Lee's troops. Pope had a wood bridge brought up from Alexandria in sections to replace the one burned by Beauregard. By August, Pope's encampment stretched from Carter's Run through Waterloo and down to Fauquier Springs. Rickett's division of McDowell's corps was stationed at Waterloo Bridge (Fauquier County Bicentennial Committee 1959:117).

Meanwhile, Jackson's men advanced on Washington around Pope's right flank, fording the Rappahannock at Hinson's Mill, just a short distance north of the Waterloo Bridge. Pope's men were involved with skirmishes at the bridge with about 6,000 forces of R.H. Anderson's division from August 24 to 27, 1862. Pope tried in vain to burn the bridge to prevent the advance, unaware that the battle for the bridge was a diversion and that he had been outflanked. Upon discovery of Jackson's position, Pope turned his troops north to meet Jackson in the Second Battle of Bull Run (Johnson and Buel 1887:516).

During the winter of 1862, Pope's troops camped along the Rappahannock Valley, establishing a base of operations at Waterloo. All of the buildings that had not been destroyed by Shields were torn down and used to build shelters for the soldiers. Only two houses were spared, one being the home of John Armstrong on Waterloo Farm. General Sedgwick used the house as his headquarters, and it remains standing today (Culpeper Historical Society 1974:55; Fauquier County Bicentennial Committee 1959:122; Johnson and Buel 1887:452).

History of Waterloo Bridge

Bridges have spanned the Rappahannock River since 1798 when the first was built at the Great Fork of the Hazel River. By 1840, bridges were in existence downstream from Waterloo at Weatley's Mill and Kelly's Ford. In 1853, Thomas Ingram built the first bridge at Waterloo. The 200' wood structure was officially known as the Sperryville and Rappahannock Turnpike Toll Bridge but commonly called the Bridge at Waterloo. By the start of the Civil War, the Waterloo bridge was the only surviving bridge over the Rappahannock, but by the end of the first year it too fell, burned by General Beauregard in his retreat from Manassas (Scheel 1982:136, 137).

After the War, Culpeper County appointed a new commission to oversee the rebuilding of roads and bridges. In June 1867, John Armstrong and William Browning were given the contract to rebuild the bridge several miles south of Waterloo at Fauquier Springs (Scheel 1982:232). It is not known when the Waterloo bridge was rebuilt; however, according to Edward Armstrong, the new bridge was a wood structure built by his father shortly after the Fauquier Springs bridge (Fauquier County Bicentennial Committee 1959:117).

The first mention of a bridge at Waterloo in county records was in the Minutes of the Fauquier County Board of Supervisor's Meeting of March 5, 1875. An unnamed person, probably John S. Armstrong, represented to the board that the bridge was "in a dangerous condition for want of repairs" (Fauquier County Board of Supervisors 1875:76). The board recommended that Messrs. Kirby and Curtis inspect the bridge and report back to the board at the next meeting. Supervisor James D. Kirby and Commissioner of Roads Mr. Curtis inspected the bridge the following week and found it

> wanting repairs to the extent of 150 dollars, and there upon appropriated same for . . . purchasing lumber to be delivered to the spot and employing some competent person to repair said bridge and render the same safe [Fauquier County Board of Supervisors 1875:72].

The final bill for the repairs came to $281.20, one third of which was paid by Culpeper County. Kirby was paid $10.40 mileage and per diem for inspecting the repairs at the bridge (Fauquier County Board of Supervisors 1875:74).

John Armstrong and his son Edward did the majority of the repair work on the bridge over the ensuing years. In 1876, John was paid $55 to effect "emergency repairs to render it temporarily safe" (Fauquier Board of Supervisors County 1876:93, 102, 104).

In 1878, Edward Armstrong was paid $300 and John Armstrong $19.75 for repairs to the bridge. This was a sizable sum and probably involved substantial rebuilding of the wood structure (Fauquier County Board of Supervisors 1878:141). Edward Armstrong noted in his memoirs that the bridge was swept away by floods several times and rebuilt by his father and himself; this was undoubtedly one of those occasions (Work Progress Administration 1978:300).

The first mention of an iron bridge at Waterloo in county records is on August 20, 1885, with the following entry in the Fauquier County Minutes:

> Board appoints R.H. Downman to audit settle and adjust the accounts between Counties of Fauquier and Culpeper growing out of the erection of two iron bridges and the subsequent repairs thereto at Fauquier White Sulphur Springs and at Waterloo and to make report [Fauquier County Board of Supervisors 1885:266].

There were no further entries in the county records relating specifically to the bridge contract or its erection, nor any record of Downman's report.

Miscellaneous small repairs were made to the bridge over the next fourteen years, including an award of $20 to R.A. Reed for "damage to his colt while crossing the Waterloo Bridge." Most likely these repairs were to the wood decking or the wood approaches rather than the metal truss (Culpeper County Board of Supervisors 1892:335; Fauquier County Board of Supervisors 1889:364, 365).

On September 18, 1899, a special meeting was called by Fauquier County concerning the substantial repairs, estimated at $400, required for the bridge. It was ordered that Rappahannock and Culpeper counties be approached for a contribution to the effort and that repairs not be made until they committed funds. Although not specifically mentioned, Rappahannock County residents must have made frequent use of the bridge and were therefore asked to contribute their fair share of the maintenance. The repairs were made by George Mason, who was paid $384.15 by Fauquier County, of which $125 was contributed by Rappahannock County and $100 by Culpeper County (Fauquier County Board of Supervisors 1899:172-173, 175, 180, 207).

In June 1911, Fauquier County found that the bridge approaches were again in need of repairs and unsafe for travel, and again contacted Culpeper and Rappahannock counties for a contribution (Fauquier County Board of Supervisors 1911:100). Over a year later, with no response from its neighboring counties, Fauquier County sent them each notice that "Waterloo Bridge is in such a state of decay that practically a new bridge will have to be constructed, that said bridge is considered dangerous for travel and unless put in good condition will have to be closed" (Fauquier County Board of Supervisors 1912:152). It was not until a year later, in September 1913, that repairs were made by the Fauquier County Center District Road Gang. The Fauquier County records do not show that the other counties ever contributed to the cost of the repairs (Fauquier County Board of Supervisors 1913:181).

By May 1917, the bridge was in such poor condition that a joint committee from both counties as well as interested citizens met at the bridge to inspect it and discuss the situation. It was agreed at the time to build a new bridge (or rather, new approach spans), that Fauquier County would pay three fifths of the cost, and that Culpeper County would pay two fifths. Furthermore, bids would be sought as soon as possible for the construction of either a steel or a concrete bridge, according to State Highway Commission plans (Fauquier County Board of Supervisors

1917:312, 325). When Culpeper's bridge committee met in July, the terms of the agreement had changed: Fauquier County would pay three fourths of the cost and Culpeper County would pay one fourth. They also noted in their record that the approaches and supports were to be of concrete. Apparently, concrete had been a point of some discussion. At the least, it was probably trumped as a permanent solution to the frequent repairs dictated by the ever flooding Rappahannock River (Culpeper County Board of Supervisors 1917:216).

On March 21, 1918, the Fauquier County Bridge Committee received bids from the Virginia Bridge & Iron Company of Roanoke (hereafter referred to as Virginia Bridge) and the Champion Bridge Company of Wilmington, Ohio, according to plans and specifications of the State Highway Commissioner. Virginia Bridge actually submitted two bids: $7,050.00 to build the bridge according to the state plans, and an alternate bid of $6,030.00 to build the bridge according to their own company plans. The bids did not include the cost of the lumber for the decking. The committee moved to accept the lower bid submitted by Virginia Bridge, conditional upon the acceptance of the agreement by Culpeper County and the approval of the alternate plans by the State Highway Commissioner. Culpeper's board met April 2, and followed Fauquier's lead by granting the same conditional approval. However, William Glidden, Bridge Engineer for the State, rejected the alternate plan, and on April 18, Fauquier County accepted Virginia Bridge's initial bid of $7,050 to build the bridge according to the state plan (Culpeper County Board of Supervisors 1918:445; Fauquier County Board of Supervisors 1918:345, 348).

Construction began November 21, 1918, and on December 19, Fauquier agreed to make a partial payment of $3,000 to Virginia Bridge. It was noted in the record that "it appears that all steel work delivered and that enough work complete to justify this payment but this does not mean Board will make any more payments until completion" (Fauquier County Board of Supervisors 1918:373).

The new concrete and steel approach spans were completed on February 23, 1919, and the final statement of its cost was recorded on July 28, 1919, as follows (Fauquier County Board of Supervisors 1919:398):

Virginia Bridge & Iron Co., contract	7,050.00
" " " " " extra excavations by order of Committee	599.06
B M Butler, for lumber	743.43
J S Hutton, building approaches and superintending work	988.08
J S Hutton, inspecting work	9.00
E W Allen, inspecting work	46.67
Total cost	9,436.24

The final entry in the county records regarding Waterloo Bridge appeared in 1922 from Fauquier County's Supervisor of Roads. Upon inspection, the Supervisor found that the bridge had been damaged by the hauling of excessive loads. He determined that the bridge was unsafe and closed it to traffic in excess of six tons (Fauquier County Board of Supervisors 1922:75).

A search of the records of the Bridge Division of the Virginia Department of Transportation, Culpeper District, produced two records on the Waterloo Bridge: an "Original Bridge Report," dated December 28, 1970, and a "Supplementary Bridge Report," dated August 21, 1992. The 1970 report listed the bridge in fair condition with a posted weight limit of eight tons. The 1992 inspection report found the bridge to be in poor condition and reduced its weight limit to three tons, the lowest rate permitted without closing. The report noted numerous deficiencies in the bridge, including severe rust, missing deck bolts, loose diagonals and counters, and deteriorated concrete piers and abutments (VDOT 1970, 1992).

Thomas Pratt and the Pratt Truss

Thomas Pratt was born in Boston in 1812, the son of noted Boston architect Caleb Pratt. Thomas was thoroughly educated by his father in the sciences, entered Rensselaer Polytechnic Institute at age 14, became an engineer with the United States Army Engineers at 18, and began a professional engineering career with Boston & Maine Railroad at age 21. At the beginning of his career, which lasted until his death in 1875, Pratt was probably the best educated bridge engineer in America. Pratt worked his entire life in the employ of various New England railroad companies, including the Providence & Worcester, the Hartford & New Haven, and the New York & Boston (American Society of Civil Engineers [ASCE] 1876:332-333; Condit 1960:108).

Pratt is best remembered for a bridge truss he designed in 1842 that consisted of two parallel chords connected by vertical wood posts in compression and double wrought iron diagonals in tension. The design, while similar in appearance to the truss recently patented by William Howe, functioned structurally opposite to the Howe truss, Howe having put the verticals in tension and the diagonals in compression. Modern engineers consider the Pratt design to be the first scientifically designed truss (Condit 1960:109). Pratt had recognized and applied a basic principle of structural engineering to truss design: reducing the length of the member in compression reduces the bending moment, allowing members of smaller cross section to be used without sacrificing overall strength. The basic design premise of a truss is to provide equal strength with less weight and material than a solid beam, and Pratt's innovation applied that principle to the design of the components of the truss itself.

In 1844, Pratt and his father were granted a patent for two truss designs, one with parallel chords and one with a polygonal top cord. Either design could be built of a combination of wood and iron, or just iron alone. The polygonal version again reflected Pratt's understanding of the application of mathematical principles in calculating the forces involved and the precise strength of the material required to counter those forces. Pratt's patent was renewed in 1858. The use of the Pratt truss for the deck of John Roebling's Niagara River Suspension Bridge in 1855 drew worldwide attention to the design and undoubtedly contributed to its increased usage. One of Pratt's best works was the Eastern Railroad's Merrimac River Bridge at Newburyport, Massachusetts. The Merrimac bridge, completed in 1865, consisted of seven wooden Pratt trusses and a center draw span of iron (ASCE 1876:334-335; Cooper 1889:11; Johnson 1929:179).

In its wooden form, the Pratt truss never attained the popularity of the Howe design, but by 1889 in its iron form it ranked first in usage (Cooper 1889:11). The first all-iron Pratt truss bridges were built by J.H. Linville for the Pennsylvania Railroad in 1850. Application of the Pratt truss in its original form reached a high point with the construction of the Erie Railroad Bridge at Portage, New York, in 1875, and the Cincinnati Southern Railroad Bridge at Cincinnati in 1876, both early landmarks in railroad bridge engineering. Literally thousands of bridges, both highway and railroad, have been built following the Pratt design or some variation (Condit 1960:111, 112, 302).

The Virginia Bridge & Iron Company

The Virginia Bridge and Iron Company was founded as the American Bridge Company in Roanoke in 1889 by C.L. Wentworth, J.B. Hunter, and C.L. Michael. In 1895, the company was incorporated as the Virginia Bridge & Iron Company (VBI) and capitalized with $50,000 (*Roanoke Times* 1966; Stevens 1930:66)

By 1904, the company was the largest steel fabricating company in the South, with a capacity of 12,000 tons annually. The product line consisted of bridges, turntables, warehouse factory buildings, and general structural iron and steel work. The company employed 175 men in the shops and 150 men in the erecting department. The plant covered 10.5 acres and included a 300' x 80' bridge shop, a large girder shop, and several smaller buildings. The plant was located on the lines of the Norfolk and Western Railroad and the Southern Railroad. The principals at the time were W.E. Robertson, President; C.E. Michael, Secretary; T.T. Fishburn, Treasurer; and C.E. Hamlin, Contracting Engineer (Charlotte County 1899-1902; Stone Printing & Manufacturing Company 1904:36-37).

Growth of the company continued through the early twentieth century, and plants were built in Memphis in 1908 and in Birmingham in 1922 (*Roanoke Times* 1936). By 1934, VBI employed 800 people, producing 5.4 million in product annually with offices in Birmingham, Memphis, Atlanta, New York, New Orleans, Los Angeles, Charlotte, Dallas, and El Paso (*Roanoke Times* 1934; Stevens 1930:66).

In 1936, VBI became a wholly owned subsidiary of the Tennessee Coal, Iron and Railroad Company, the largest producer of steel in the South (*Roanoke Times* 1936).

In 1952, VBI was merged into the American Bridge Company, a subsidiary of the United States Steel Corporation and the largest bridge company in the United States. VBI's facility in Roanoke served as the headquarters of the Southern Division of the American Bridge Company until 1965 when the plant was closed (United States Steel Corporation 1975:18, 32).

According to *A Survey and Photographic Inventory of Metal Truss Bridges in Virginia, 1865-1932*, a study conducted by the VDOT Research Council in 1973, the Virginia Bridge & Iron Company built a total of sixty-five truss bridges in Virginia. The company built six other truss bridges in addition to the Waterloo Bridge within the Culpeper VDOT Construction District (Deibler 1973). One other VBI bridge, Clarkton Bridge (VDOT Bridge No. 6902), in Charlotte County, is included in the seventeen historic metal truss bridges recorded by VDOT in 1993-1994, of which this report is a part.

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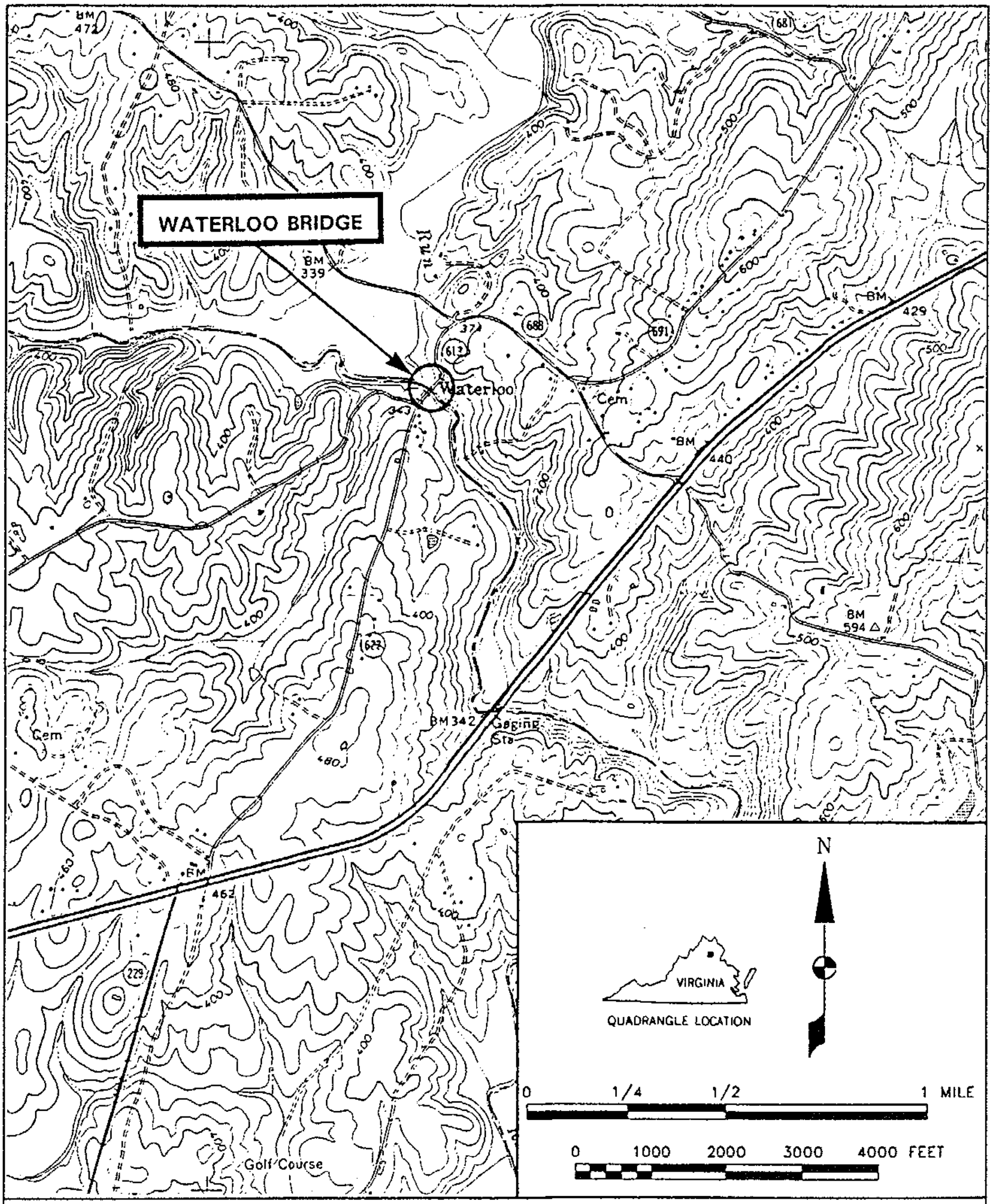

FIGURE 1: Location Map

SOURCE: USGS Jeffersonton, VA, 7.5 Minute Quadrangle, 1966 (Photorevised 1983)

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FIGURE 2: Original Bridge Report, Bridge No. 6906, December 28, 1970

SOURCE: Virginia Department of Transportation 1970

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FIGURE 3: Original Bridge Report, Bridge No. 6906, December 28, 1970 *SOURCE: Virginia Department of Transportation*