HISTORIC AMERICAN ENGINEERING RECORD

ERIE RAILROAD, BUFFALO DIVISION, BRIDGE 361.66
(Portage Viaduct)

HAER No. NY-54

Location: Norfolk Southern Railway's Southern Tier Line over the Genesee River between the towns of Genesee Falls (Wyoming County) and Portage (Livingston County), New York, within Letchworth State Park at milepost 361.66.

Portage Viaduct is located at latitude 42.577250, longitude -78.047680. The coordinate marks the east abutment of the bridge. It was obtained in 2017 by plotting its location in Google Earth. The location has no restriction on its release to the public.

Present Owner: Norfolk Southern Corporation (Norfolk Southern Railway)

Present Use: Demolished railroad bridge, replaced on December 11, 2017

Significance: Portage Viaduct was a major infrastructure component of the Erie Railway's Buffalo Division route between Buffalo and Hornell, New York. The Portage Viaduct was the first major railroad bridge designed by noted nineteenth-century American bridge engineer George S. Morison. Its sturdy original design and major improvements in 1903 and 1944 gave the bridge a service life of 142 years. Although not technologically innovative, the Portage Viaduct was a large example of its type for its time, and it occupies precedent-setting place in the evolution of American metal railroad viaducts.

Historian: Matt Kierstead, Milestone Heritage Consulting, 2018

Project Information: The Portage Viaduct was recorded under the authority of a 2014 Memorandum of Agreement (MOA) between Norfolk Southern, the Federal Highway Administration, Advisory Council on Historic Preservation, the New York State Department of Transportation, the New York State Office of Parks, Recreation and Historic Preservation, the New York State Historic Preservation Officer, and the National Park Service. The MOA specified documentation of the viaduct by the Historic American Engineering Record (HAER) as part of the mitigation for the removal of the bridge by Norfolk Southern, who planned to replace it with a steel arch railroad bridge located 75 feet upstream. (The replacement bridge opened to traffic on December 11, 2017.)

HAER sponsored the Portage Viaduct Recording Project in 2015–18 under the direction of Christopher Marston, HAER architect and project leader. HAER contracted with Milestone Heritage Consulting to prepare the documentation. Matt Kierstead led the fieldwork and research and completed the history. Michael Froio completed the photography. Special thanks to Howard Swanson, Norfolk Southern Railway assistant chief engineer; William D. Burt, historian; William Doyle, historian; Dario Gasparini, structural engineer; Frank Griggs Jr., historic bridge restoration consultant; and Barney Martin, former president/CEO, Modjeski & Masters, for their advice, information, and peer review of the report.

Chronology

July 1, 1851	Buffalo & New York City Railroad begins Portage timber trestle construction.
August 14, 1852	First train over Portage timber trestle.
May 6, 1875	1852 Portage timber trestle burns.
May 10, 1875	Erie Railway awards Portage Viaduct ironwork contract to Watson Machine Co. of Paterson, New Jersey.
June 8, 1875	First ironwork delivered to Portage Viaduct construction site.
June 13, 1875	First Portage Viaduct ironwork erected.
July 29, 1875	Last Portage Viaduct ironwork erected.
July 31, 1875	Portage Viaduct tested and placed in service.
May 25, 1903	Erie Railroad begins 1875 approach and main truss spans replacement project.
December 13, 1903	Truss spans replacement project completed.
August 9, 1943	Erie Railroad begins reconditioning 1875 towers.
September 10, 1944	Towers reconditioning project completed.
1976	Consolidated Rail Corporation (Conrail) acquires the Erie-Lackawanna Railway, including the Portage Viaduct.
1999	Norfolk Southern Railway acquires the “Southern Tier Line” between Buffalo and Suffern, New York—which includes the Portage Viaduct—as part of the breakup of Conrail.
2015	HAER starts documentation of Portage Viaduct as construction begins on replacement bridge.
December 11, 2017	Norfolk Southern Railway opens replacement Genesee Arch Bridge (NS SR-361.66) to traffic.
March 20, 2018	1875 Portage Viaduct ironwork removal completed. (Stonework removal completed May 2018.)

PART I. HISTORICAL INFORMATION

A. Physical History:

1. Date of Construction: Portage Viaduct replaced an 1852 timber trestle that burned on May 6, 1875. The contract for the ironwork was awarded on May 10, 1875, and the first ironwork was erected on June 13, 1875. The bridge was tested and placed in service on July 31, 1875.[1] The trusses were replaced in 1903, and the towers were strengthened in 1944.

2. Engineer: George Shattuck Morison, principal assistant engineer, Erie Railway

U.S. bridge engineer George S. Morison (1842–1903) was "instrumental in the development of the steel bridge industry in the 1880s and 1890s."[2] Morison was born December 19, 1842, in New Bedford, Massachusetts. He graduated in 1863 from Harvard University, where he excelled in mathematics, and then graduated from Harvard Law School in 1866. Morison was admitted to the New York State Bar and briefly practiced law in New York City. After a year Morison decided not to continue in law, and at age 25, with no formal training, he decided to pursue employment in civil engineering. In 1867, he began working under engineer Octave Chanute on the Hannibal Bridge over the Missouri River at Kansas City, Missouri. From 1871 to 1873, Morison was chief engineer for the Detroit, Eel River & Illinois Railroad. In April 1873, Chanute, then chief engineer of the Erie Railway, invited Morison to join him as the Erie's Eastern Division resident engineer.[3] Chanute assigned Morison the job of reconstructing and strengthening the Erie's many wood and early iron bridges, which could not support the new steam locomotives. This assignment presented Morison with a bridge engineering "field laboratory."[4] Chanute quickly promoted Morison to principal assistant engineer. Morison's first opportunity to design a major railroad bridge came in May 1875, when the Erie Railway's 1852 wooden Portage trestle spanning the Genesee River at Genesee Falls and Portage, New York, burned. Morison resigned from the Erie in November 1875, three months after the new Portage Viaduct was complete. He established his own consulting business, advised banks and railroads on construction and management, served as a director of several eastern and midwestern railroads, and was a partner in the Morison, Field & Co. bridge engineering and construction firm of Buffalo, New York.[5]

In 1880 Morison designed and built his first major midwestern U.S. river crossing, the Chicago, Burlington & Quincy Railroad bridge across the Missouri River at Plattsmouth, Nebraska. Following the success of that structure, Morison became one of the great U.S. bridge engineers of the late nineteenth century. Between 1880 and 1901, he designed over two dozen long-span

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[1] George S. Morison, "The New Portage Bridge," *Transactions of the American Society of Civil Engineers* 4 (November 1875): 1–9.
[2] Clayton B. Fraser, "Nebraska City Bridge," HAER NE-2, Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, 1986.
[3] E. Gerber, H. G. Prout, and C. C. Schneider, "Memoir of George Shattuck Morison," *Transactions of the American Society of Civil Engineers* 54 (June 1905): 513.
[4] Fraser, "Nebraska City Bridge," 21.
[5] Gerber, Prout, and Schneider, "Memoir of George Shattuck Morison," 514.

bridges, including ten crossing the Missouri River, five over the Mississippi, and others over the Columbia, Des Moines, Ohio, Snake, St. Johns, and Willamette rivers. His superlative structures included the 10,560'-long, fifty-two-span, 1889 Ohio River Bridge at Cairo, Illinois, then the longest metal bridge in the world with the longest spans in the world (518'), and the 1892 Mississippi River Bridge at Memphis, Tennessee, then the longest single cantilever span (790') in the United States.[6] Morison also served on many important engineering project boards and commissions. His Isthmian (Panama) Canal route investigations and intervention with President Theodore Roosevelt were instrumental in the selection the canal route. In 1895, he was elected president of the American Society of Civil Engineers.[7] George S. Morison died at age 61 in 1903. Noted fellow U.S. bridge engineer Ralph Modjeski, longtime assistant to Morison, referred to him as the "father of bridge building in America."[8]

3. Builder/Contractor/Supplier: The Watson Manufacturing Company of Paterson, New Jersey, fabricated and erected the Portage Viaduct's original 1875 wrought-iron components, but other unnamed New York and Pennsylvania suppliers reportedly fabricated a portion of the iron.

Brothers William G. and James Watson, who immigrated to Paterson from Chorley, England, in 1829, founded the Watson Manufacturing Company. The brothers had acquired mechanical knowledge working in textile mills as children, and eventually gained management positions through apprenticeships. In 1851, they established W. G. & J. Watson Machine Shop and Foundry, casting large water turbine blades. Ten years later, the Watsons purchased property on Railroad Avenue in Paterson and erected their own steam-powered machine shop. They incorporated as the Watson Manufacturing Company in 1865. The Watsons won a contract for an iron bridge on Straight Street in Paterson in 1868; this soon resulted in a successful bridge-building business. After a fire in 1872, the Watsons reconstructed and greatly enlarged their shops. Watson Manufacturing was located next to the Erie Railway line, and the company established a strong working relationship with the Erie. Watson's workforce of 600 to 800 men fabricated and erected about 100 bridges for the Erie, as well as bridges for Passaic County in New Jersey, New York City, and elsewhere over the next three years. The company's prolific bridge-building stint ended in 1875 when fire destroyed their new Paterson shops, dealing a major financial blow. Watson soon ceased bridge fabrication and focused on general machine shop work, including support for Paterson's silk industry. In 1885 the Watsons changed the business name to the Watson Machine Company, and in 1907 they manufactured the "Watson Conover Automobile." The company's name changed again in the twentieth century to Watson Machine International, which continued to make and repair machinery for the wire and cable

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[6] Francis E. Griggs Jr., "Geo. S. Morison, Ch. Eng'r," *Civil Engineering Practice, Journal of the Boston Society of Civil Engineers Section, American Society of Civil Engineers* 24, no. 2 (Fall/Winter 2009): 19, 24–25.
[7] Griggs, "Geo. S. Morison, Ch. Eng'r," 32–35.
[8] Henry Petroski, *Engineers of Dreams: Great Bridge Builders and the Spanning of America* (New York: Vintage Books, 1996), 172.

industry, and eventually electronics and fiber optics. When the company finally closed in the late 1990s, it was among Paterson's longest-running industries.[9]

The Watson Manufacturing Company was known for building many Post truss bridges for the Erie Railway and other railroads in the 1860s and 1870s. Simeon S. Post (1805–72) became resident engineer for Erie Railway predecessor New York & Erie Railroad in 1840. The Erie soon made Post its superintendent of transportation, and in 1851 he was made chief engineer. Post left the Erie in 1858 and established his own engineering consulting business. In the early 1860s, he developed the "Post truss," his own proprietary, stiff, economical truss variation that incorporated parallel inclined timber compression and wrought-iron tension members. The first Post truss bridge on the Erie was built over Moodna Creek at Washingtonville, New York, in 1865. Post trusses became popular through the early 1870s, especially for U.S. transcontinental railroad long-span river crossings, and reached lengths of 360'. In 1870, Post licensed his truss designs to the Watson Manufacturing Company, where his son Andrew was a managing partner. Soon after, the Post truss popularity waned in favor of the superior Whipple, Warren, and Pratt truss types.[10] A particularly notable Watson-built Post truss bridge was the first Rosendale Trestle (1872) over the Rondout Creek at Rosendale, New York. This 940'-long, 150'-high viaduct, briefly the biggest of its kind in the world, was replaced by a King Bridge Company Pratt deck truss in 1895. The Watsons also built the Erie's 560'-long, skewed, four-span Post truss bridge across the Susquehanna River at Susquehanna, Pennsylvania.[11]

4. Original Plans and Construction:

1852 Timber Trestle

The Erie Railway built the Portage Viaduct in 1875 to replace a massive timber railroad trestle crossing the Genesee River Gorge (See Figure 1). The timber trestle, designed by Buffalo and New York City Railroad's chief engineer, Col. Silas Seymour, and built by the railroad's contractors, Lauman, Rockafellow & Moore, had been completed in 1852 as part of the Buffalo and New York City Railroad's Buffalo line between Buffalo and Hornellsville, New York. The Buffalo and New York City Railroad (B&NYC) line was acquired by the Erie Railway in 1861. A spectacular fire destroyed the Portage trestle on May 6, 1875. A brief description of the 1852 trestle is relevant, as its 1875 successor was built utilizing portions of the original masonry substructure, dictating its location, orientation, size, proportions, and arrangement (See Figure 2). The 1852 trestle, an engineering marvel in its own right, was the largest of its type in the world and a major regional tourist attraction (See figures 3 and 4). According to the late nineteenth-

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[9] Patrick Harshbarger, "Property Report for Watson Machine, 24–102 Railroad Avenue, Paterson, NJ," New Jersey Department of Environmental Protection, Historic Preservation Office, Intensive-Level Survey of Paterson Industrial Mills, Hunter Research, 2012, 8.
[10] Patrick Harshbarger, "Addendum to Ponakin Bridge," HAER MA-13, Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, 1990, 3–9.
[11] Victor C. Darnell, *Directory of American Bridge-Building Companies, 1840–1900*, Occasional Publication No. 4 (Washington, DC: Society for Industrial Archeology, 1984), 34.

century bridge engineer John Edwin Greiner, "This viaduct was always considered the boldest attempt ever made in timber trestles."[12]

The 800'-long timber trestle carried the Erie's 6'-wide gauge, single-track rail line 234' above the Genesee River bed on sixteen spans supported by fifteen towers on masonry piers and two end abutments (See Figure 5). Each 50'-long truss span consisted of three parallel, 14'-deep, four-panel timber deck trusses connected by transverse top and bottom struts and diagonal X-braces at the panel points. The bottom ends of each truss were supported by narrow transverse towers, the tallest 190' high, each consisting of three parallel, closely spaced tied timber bents made of 14"-square posts. In transverse section, each bent was 25' wide at the top and had vertical posts directly supporting the trusses, flanked by inclined posts with a 1:8 outward battered profile. Each bent was divided into horizontal panels by lateral 6" x 12" horizontal struts, with each panel containing a pair of X-braces. The towers were tied horizontally by 6" x 16" longitudinal struts with diagonal knee braces, forming a continuous system of trestlework. The timber framing was designed so that worn members could be individually removed and replaced without affecting carrying capacity. The tower at the foot of the east riverbank, near the center of the bridge, was approximately three times wider at the base than the other towers, acting as a transverse outrigger brace providing additional lateral stability for the trestle. The towers rested on fifteen locally quarried, horizontally coursed ashlar sandstone masonry piers 50' apart on centers, the tallest one rising 30' above the flat Genesee River bottom. The east bank pier was approximately three times as long as its flanking piers to support the extra-wide tower at that location. One span on the east bank crossed the bed and towpath of the Genesee Canal. The bridge was equipped with water tanks and permanent watchmen in case of fire.[13]

The 1852 Portage timber trestle incorporated a series of four-panel deck trusses between each pier to support the track. Examination of historic photographs shows that Silas Seymour employed a variation of the Long truss, with a supplemental diagonal outer brace crossing between every two panels (See figures 3-6). Col. Stephen H. Long's design, patented in 1830, consisted of wood vertical posts, paired diagonal braces and a single counterbrace crossing within each framed panel. The Long truss introduced the concept of prestressing to American bridge design. Long's agents built several Long trusses for a variety of railroads in the mid-1800s, as they were capable of handling heavy rail loads with minimal deflection. Ultimately the Long truss was superseded by the Howe truss, designed by William Howe and patented in 1840, which replaced the vertical timber post with an adjustable wrought-iron rod as the tension member. Howe trusses eventually became the most popular timber truss type employed on railroads from the 1850s to the 1870s (including the Erie) because they used standardized framing members and connections, incorporated prefabricated iron members, and could be quickly erected in remote locations.[14]

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[12] J. E. Greiner, "The American Railroad Viaduct: Its Origin and Evolution," *Transactions of the American Society of Civil Engineers* 24 (October 1891): 350.

[13] "'High Bridge,' Portage, New York," *Civil Engineer & Architects Journal* 16, no. 227 (February 1853): 65.

[14] Justine Christianson and Christopher H. Marston, executive editors, *Covered Bridges and the Birth of American Engineering* (Washington, D.C.: Historic American Engineering Record, National Park Service

1875 Portage Viaduct

The Portage Viaduct's successive railroad company owners, referred to in collective shorthand as "the Erie," called the structure Buffalo Division Bridge 16 or Bridge No. 361.66, referring to the distance in miles from the east abutment of the bridge east to the Erie's New York Harbor ferry terminal at the west edge of the Hudson River at Jersey City, New Jersey. The structure was a "viaduct"—that is, a bridge with distinct spans supported by separate braced towers—as opposed to a "trestle," which has a continuous deck supported by many closely-spaced bents connected by multiple horizontal ties.[15] The Portage Viaduct was oriented at a skewed angle to the compass points. For simplicity, and consistent with railroad timetable direction, this documentation calls the structure's Portage end the east, the Genesee Falls end the west, the upstream side the south, and the downstream side the north. This section of the historical report describes the 1875 Portage Viaduct as it was built. Subsequent sections discuss major alterations and present a description of the bridge as it appeared until its demolition.

According to multiple sets of original engineering plans in Norfolk Southern Railway archives, the Portage Viaduct's metal superstructure was 818' long between masonry abutments, 203'-8" high from the base of the tallest tower to the top of the rail, and 69'-8" wide across the base of the widest (tallest) towers.[16] The tallest of the concrete and masonry piers standing on bedrock in the Genesee River was 31'-6" tall for a total structure height of 235'-2". As indicated on engineering plans, the metal superstructure included, from east to west, thirteen spans, numbered 1 through 13, and six towers lettered A through F incorporating twelve paired bents numbered 1 through 12 (See Figure 7). The masonry substructure included, from east to west, an east abutment, twelve masonry piers numbered 1 through 12 corresponding to the towers, and a west abutment.

The bridge's designer, George S. Morison, presented the Portage Viaduct's design considerations, structural description, and construction techniques in a detailed paper titled "The New Portage Bridge," which he delivered before the American Society of Civil Engineers (ASCE) in November 1875 and which ASCE reprinted in its *Transactions*. That short, seven-page paper contains valuable information and forms an important basis for this narrative. At the time of construction, the bridge was on a 50-mile-long section of single-track rail line that the Erie Railway planned to double-track. The bridge also sat at the eastern foot of a 1.5-mile long, 1-percent westbound grade rising toward Castile that the Erie planned to reduce by raising the western approach and elevating the actual bridge deck about 20'. When the 1852 bridge burned in 1875, the Erie was able to temporarily divert traffic but needed to replace the bridge rapidly and with the least expense in the wake of the Panic of 1873. The Erie was struggling financially at that time, and ultimately entered receivership in early June 1875. Despite financial issues,

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2015), 58-61, 130-142; Dario Gasparini, structural engineer, personal communication with the author, December, 2018.

[15] Greiner, "American Railroad Viaduct," 359.

[16] The 1875 bridge project is documented in a set of engineering plans titled Erie Railroad Co., Buffalo Division, Portage Viaduct, var. dates, 1875, Drawing Nos. MF225257–MF225267, MF225682–MF225699, in the Bridge (BR) 361.66 plan archives of Norfolk Southern Corporation / Norfolk Southern Railway.

Morison designed a robust replacement that allowed for expansion of the structure in the future, while minimizing first costs. Morison's replacement Portage Viaduct design was robust. He designed a single-track bridge with tower columns strong enough to support a future second and/or elevated track, and paired trusses on 20' centers so that a second set could later be inserted between them to carry a second track.[17]

1875 Substructure

After the 1852 timber trestle burned, contractors examined the fifteen piers, all located on 50' centers, and the abutments.

According to Morison,

> the top surfaces of the river piers were badly shattered by the fire, and the lower courses of stone were badly broken by the action of frost and water, the stone of which they were built not being of the best character. In placing the pedestals, the broken upper stones were removed and a good bearing secured. As a protection to the masonry, the entire upper surface of the piers was covered with a thin layer of *beton coignet*. The lower courses of the piers, which rest on the bottom of the river, were enclosed in cribs of sawn oak timber, placed 18 inches from the stone, and the space between the timber and stonework filled with *beton* and well rammed.[18]

The east bank abutment and piers 1 through 7 had been badly damaged by fire and were removed to ground level and rebuilt with regularly coursed, quarry-faced blocks of Berea (Ohio) sandstone. The two westernmost piers were abandoned, the west abutment was removed, and new piers numbered 11 and 12 and a new west abutment were constructed 18' west of their predecessors. This alteration moved them away from the edge of the precipitous west gorge cliff. Three of the piers in the river were abandoned and removed, and the remaining ones, numbered 8, 9, and 10, were retained and repaired. Piers 8, 9, and 10 were covered for protection from frost and water with *beton coignet*, a concrete material.[19]

G. G. Stevens & Fagan of Brooklyn, New York, and John Hichler of Buffalo completed the masonry work.[20] The New York & Long Island Coignet Stone Company of Brooklyn did the *beton coignet* work.[21]

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[17] Morison, "New Portage Bridge," 1–2. A discussion of *beton coignet* appears on page 25.
[18] Morison, "New Portage Bridge," 8.
[19] Morison, "New Portage Bridge," 1–2.
[20] "The New Portage Viaduct," *Scientific American Supplement* 1, no. 4 (January 22, 1876): 55.
[21] Charles Macdonald, "On the New Portage Bridge," *Transactions of the American Society of Civil Engineers* 5 (February 1876): 238.

1875 Superstructure

For placement on top of the inherited substructure described above, Morison designed an iron viaduct (See figures 8 and 9) with six towers and thirteen deck truss spans: one 118' span, two 110' spans, and ten 50' spans.[22] Watson Manufacturing Company of Paterson, New Jersey, fabricated and erected the ironwork. Other, unnamed New York and Pennsylvania suppliers (discussed in Section B: Historical Context, below) reportedly fabricated a portion of the iron. The as-built description below quotes from Morison's 1875 ASCE paper at length, with bracketed insertions for clarity and in reference to following descriptions of later strengthening projects. Morison's component designations and terminology are largely adhered to throughout this documentation.[23]

According to Morison, the trusses (See figures 10, 11 and 12) were:

> of the simple Pratt pattern, with no other peculiarity other than they are made very narrow, the top chord being of I shape, formed of a plate and four angles. The laterals are attached to short vertical pins which pass through yokes fitting over the truss pins. . . . The trusses are placed 19 feet 10 inches apart between centers. . . . To give additional stiffness to so narrow a chord, a double set of laterals are used, attaching at the middle of each panel as well as to the pins. One end of each long truss is bolted to the iron capital of the column, and the other is placed on rollers, but connected with the next truss by iron loops passing over the end pins of each span, and which allow only the amount of motion needed for expansion. The short spans over the towers are bolted to the capitals at both ends; the others are arranged in the same manner as the long spans. The end pins of the 50-foot spans are placed 6 inches from the center of the columns, and those of the long spans only 3 inches, so that under a full load the center of weight comes directly in the line of the center of the column.[24]
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> The trusses are supported by wrought-iron [vertical] columns, the ends of two adjacent trusses resting upon a single column [See figures 13 and 14]. The pairs of columns supporting the opposite trusses are in the same vertical plane, but are inclined towards each other with a batter of 1 in 8; they are united with wrought-iron [horizontal] struts 25 feet apart and diagonal tie rods [X-bracing], thus forming a two post bent; each column is connected with the parallel column of the adjoining bent by a similar arrangement of struts and diagonal ties; the four columns with connecting bracing are thus made to form a single skeleton tower, 20 feet wide and 50 feet long at the top, surmounted by a 50 feet span of bridge, having the same length at the bottom and a width varying with the height of the tower. There are six of these towers, called for reference A, B, C, D, E and F, of

[22] Morison, "New Portage Bridge," 2.
[23] Erie Railroad Co., Buffalo Division, Portage Viaduct, var. dates, 1875, Drawing Nos. MF225257–MF225267, MF225682–MF225699, in the Bridge (BR) 361.66 plan archives of Norfolk Southern Corporation / Norfolk Southern Railway.
[24] Morison, "New Portage Bridge," 6.

which towers D and E are the largest, having a total height, from masonry to rail of 203 feet 8 inches, and being 69 feet 8 inches wide between centers of columns at the base.[25]

The columns are made in 25-foot lengths. They are formed of three plates and four angle irons, with a latticing on fourth side, so that the interior of the column is accessible for painting. The angles are all 4 x 4 x ½ inches, and the plates are all 15 inches wide; the back plate is of the same thickness for the whole length of each column, while the thickness of the side plates is varied to provide for the increased strains in the lower sections. The thinnest plate used is ½ inch thick, this being the back plate of the columns on which the ends of two short spans are carried.[26] The ends of the several [column] lengths are squared and faced, and they rest directly upon one another without joint boxes of any kind; the upper end of each length is fitted with two projecting plates which form a tenon; the length above fits over the tenon plates and is secured to the lower length by a turned pin of 1-7/8 inch diameter passing through carefully bored holes; this same pin serves for the attachment of the longitudinal [diagonal tie] rods. A second pin at right angles to this one, is placed a few inches below the joint and forms the attachments for the transverse strut and [diagonal] ties; the end of the strut is fit in between the side plates of the column and is held by the pin; the diagonal ties are attached to the pin on each side of the column; they being everywhere in pairs. The longitudinal strut, which is nearly 50 feet long, is built in the form of a light lattice truss, is 2 feet deep and 1 foot wide, with the ends squared and butting against the side of the column; it is further secured by bolting it to lugs attached to the side plates and is stiffened by angle iron braces connecting it with the corresponding transverse struts, 10 feet from each end. [The 1875 bridge as built had no longitudinal struts connecting the bottoms of the column legs in towers A, B, D, and E.] The wrought-iron columns are surmounted by capitals of cast iron.[27]

With great heights . . . the side batter of the posts necessitates the use of very long transverse struts in the lower sections of the towers, which are objectionable, requiring at Portage [towers D and E], intermediate vertical posts and lateral bracing to stiffen them, while the expansion and contraction of the iron becomes very considerable.[28] … The lengths of the transverse struts [in these towers] vary from 20 feet at the top of the tower to 64 feet at the lowest joint in the main towers; the three lower [transverse] struts are made in two parts, connected with splice plates and supported by a light central post; the first and second struts are further stiffened by an intermediate longitudinal strut and a system of horizontal diagonal rods.[29]

The columns rest upon cast iron pedestals; those on the north side of the bridge being secured by dowels to a cast iron plate sunk in the masonry, and those on the south side

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[25] Morison, "New Portage Bridge," 3.
[26] Morison, "New Portage Bridge," 4.
[27] Morison, "New Portage Bridge," 4–5.
[28] Morison, "New Portage Bridge," 7.
[29] Morison, "New Portage Bridge," 4–5.

> being placed on rollers rolling at right angles to the axis of the bridge; the pedestals are connected by eye-bars to take up the thrust due to inclination of the posts, and are kept apart by struts adjustable with wedges, to resist the inward thrust caused by screwing up the diagonals. This arrangement, which is not needed in smaller iron structures, was thought important here, in order to relieve the masonry, which is old, from all possible thrust, while the use of an adjustable strut makes it possible to throw all the tensile strain due to the inclination of the posts, on the horizontal ties, leaving the diagonals to perform their function of wind and vibration stiffness.[30]

5. Alterations and Additions:

1903 Strengthening

The Erie Railroad undertook the first of two major, twentieth-century Portage Viaduct improvement projects in 1903 (See Figure 15). Ever-increasing freight traffic volume, weight and speed rendered the original 1875 iron deck truss spans inadequate, so the Erie replaced them with stronger, steel deck truss and girder spans designed to carry the anticipated larger train loads pulled by newly-purchased fleets of heavier Erie "Consolidation" type steam locomotives. As the original structure had been designed to carry two tracks, the towers were considered adequate to support the new spans.[31]

The original 1875 iron truss spans were 19'-10" apart on centerlines, and their ends rested directly on the tops of the tower columns. The Erie designed the new steel truss and girder spans with 14' centerlines so that they could be installed within the spaces between the old trusses without interrupting train service. In order to support the ends of the new spans, a fabricated transverse steel plate girder cross-cap structure, or "header," was riveted between the tops of the two transverse columns of each tower bent. The truss span headers were 10' deep, with solid web plates at the sides and an open, X-braced center panel (See Figure 16). The deck girder span headers were 6' deep and of solid plate construction (See Figure 17). Transverse lateral stresses were transmitted from the spans to the towers by the headers. Longitudinal stress transmission from spans to towers was preserved by reattaching the upper ends of the top longitudinal panel X-brace rods to modified mounts at the tops of the columns.[32]

The Erie replaced the 1875 wrought-iron deck trusses (spans 7, 9, and 11) with riveted and pin-connected steel Pratt deck truss spans. Spans 7 and 9 were 100' long, 14' deep on top and bottom chord centers, and incorporated seven panels on 14'-3½" pin centers (See Figure 18). Span 11 was 118' long, 14' deep on top and bottom chord centers, and incorporated nine panels on 13'-1¼" pin centers (See Figure 19). The ends of each truss rested on the tower bent header girders,

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[30] Morison, "New Portage Bridge," 4.
[31] "The New Spans of the Portage Viaduct, Erie R.R.," *Engineering Record* 51, no. 5 (February 4, 1905): 120–21; A. M. Knowles, "Strengthens Viaduct for Heaviest Power," *Railway Age* 119, no. 5 (August 4, 1945): 199; A. M. Knowles, "Strengthening Old Viaduct Proves Big Task," *Railway Engineering and Maintenance* 41, no. 8 (August 1945): 773.
[32] "New Spans of the Portage Viaduct, Erie R.R.," 120–21.

with one end of each truss bolted through slots in the header to allow for temperature expansion and contraction movements. The truss top chords were rectangular in section, with solid tops and sides built from three lengths of plate with riveted splice bars. The top chords had open bottoms with lace bars and batten plates flanking the tops of the vertical post connections. The vertical posts were rectangular in section with plate web inner and outer faces and lace bar sides with batten plates at the top and bottom ends. The bottom chords in the two panels at each end were built-up, riveted members similar in construction to the top chords, but of shallower depth. The bottom chord members in the remaining center panels consisted of two parallel pairs of steel eyebars connected to pins at the panel points. The truss panels incorporated diagonal brace members, with the two outer panels of the short and long trusses containing one parallel pair of eyebars oriented in the characteristic Pratt truss mirrored "down and in" orientation. The remaining three center panels contained diagonal eyebars crossed in an X configuration, with one pair of eyebars sloping in one direction and a single perpendicular eyebar counterbrace placed between them, incorporating a threaded tensioning turnbuckle. The top and bottom truss chords were laterally connected with built-up, riveted upper and lower transverse struts located at the panel points. The struts consisted of built-up riveted beams with web plates at the ends; the centers of the lower struts contained X braces, and the shallower upper struts contained lace bars. Each set of columns and struts was further stiffened by a large transverse X brace attached to knee brace plates at the column-to-strut intersections. Each top and bottom panel contained a set of lateral X-brace rods 1½" in diameter with clevis ends attached to gusset plates at the top chord and tabs on the pins at the bottom chord. The top and bottom chords, columns, and diagonal members were connected by horizontal steel pins of 2¼", 2", and 1¾" diameters, depending on locations.[33]

The Erie replaced all of the 1875, 50' wrought-iron deck trusses (spans 1 through 6, 8, 10, 12, and 13) with riveted structural steel deck girder spans 50' long and 6' deep (See Figure 20). Each girder web was made of four plate sections with riveted splices, subdivided into eight panels by web stiffener angles. Each girder span was internally braced at the web splice points with transverse frames with X braces and lateral X-brace rods across the top of each panel. Adjacent girders were riveted to form a continuous rigid structure across the towers except at expansion points, where they were bolted and had slotted connections to the tops of the headers. Girders were connected to trusses by riveted connections at the truss end posts supplemented by knee braces.[34]

The Erie designed and sequenced the project carefully so they could replace the old spans without interrupting traffic. The work made extensive use of compressed-air rivet guns supplied by a gasoline-engine-driven Fairbanks-Morse air compressor and flexible air lines distributed by a system of temporary pipes and hoses. Lifting was accomplished with a single Lidgerwood drum hoist located at the center of the viaduct. The new deck spans were designed to fit inside the old ones so they could be assembled or lowered within them. The transverse header girders for supporting the ends of the new spans were installed at the tops of each tower bent first. The 50' girder spans were then installed one at a time between the old spans, using a pair of small

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[33] "New Spans of the Portage Viaduct, Erie R.R.," 120–21.
[34] "New Spans of the Portage Viaduct, Erie R.R.," 120–21.

wheeled timber travelers mounted on a temporary track that straddled the active track. The upper laterals and bracing of the old truss were removed, the new girders lowered into place, the transverse and lateral bracing installed, and the rest of the old truss removed, taking each short span out of service for just two-and-a-half hours. For the truss span installations, the Erie bridge forces employed a special traveler, essentially a temporary rolling timber Howe truss bridge with no lower transverse members, which moved on rollers on the temporary construction track and was large enough for trains to pass through it. The traveler was rolled into place over each long truss span and placed so it rested on the bridge's flanking tower bents. The construction crew suspended a work platform inside the old truss, assembled the new trusses on the platform, attached the ends to the tower headers, re-laid the track, and removed the old truss in essentially the same manner as the shorter spans. Each truss replacement took sixteen men fifteen days to complete, stopping only for brief intervals when trains passed during the final lowering of each truss onto its tower headers.[35]

The 1903 improvements required about 500 tons of steel. Work began May 25, 1903, and the new spans were in service by December 13, 1903 (See Figure 21). Mason R. Strong, engineer of bridges, under the direction of C. W. Bucholz, chief engineer, designed the improvements and erection methods. The McClintic-Marshall Bridge Co. in Pottstown, Pennsylvania, under Contract No. 710-A, fabricated the deck trusses and girder spans, and the Erie Railroad's bridge-erecting forces installed them.[36]

1943–44 Reconditioning

The Erie Railroad undertook the second of its two major Portage Viaduct improvement projects in 1943–44, as World War II resulted in heavy rail traffic (See Figure 22). The Erie purchased new diesel-powered locomotives for its long-distance Jersey City–Chicago main line freight trains, and planned to reassign its heavy "Berkshire" type steam locomotives to the Buffalo Division. The original Portage Viaduct towers were unable to support the Berkshires, so the Erie's 1943–44 reconditioning project was designed to accommodate them. The work focused on the most inadequate or worn parts of the vertical tower elements, including vertical column section tenon joints, horizontal struts and their column connections, diagonal tie braces (rods), and column bases and rollers.[37]

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[35] "The Reconstruction of the Portage Viaduct," *Engineering Record* 51, no. 9 (March 4, 1905): 252–54.
[36] "New Spans of the Portage Viaduct, Erie R.R.," 121; "Reconstruction of the Portage Viaduct," 254. The 1903 project is documented in two sets of engineering plans titled McClintic Marshall Construction Co. Contract Nos. 710A and 710B, var. dates, 1903, Drawing Nos. MF225236–MF225243-BR 361.66; and Erie Railroad Co. Buffalo Division, Portage Viaduct, var. dates, 1902–1903, Drawing Nos. MF115262–MF225277, MF225329–MF225345, in the Bridge (BR) 361.66 plan archives of Norfolk Southern Corporation / Norfolk Southern Railway.
[37] Knowles, "Strengthens Viaduct," 199–200, and "Strengthening Old Viaduct," 773–74; Erie Railroad Co., "Diesels to Conquer Heavy Erie Grades," *Erie Railroad Magazine,* October 1944, 6–7; Erie Railroad Co., "Portage Viaduct Strengthened and Reopened," *Erie Railroad Magazine,* October 1944, 6–7.

The original joints between the 25'-long vertical tower column sections were inherently weak, relying on the butting column end faces and 6"-long riveted tenon alignment plates, as well as the stiffness of the original tower struts and brace rods. However, these were all inadequate for projected loads. To stiffen the columns, the Erie bridge department removed the riveted lace bars and batten plates on the open, inside faces of the columns, and realigned and reinforced the joints with 14"-long by ½"-thick splice plates riveted to the inside faces of the column side plates (See Figure 23). They then stiffened the columns by fillet welding long, vertical, 18"-wide, 5/8"-thick steel cover plates over the open inner sides of the columns (See Figure 24). The original bridge movement-compensating roller nests at the bases of some of the south columns had worn unevenly, causing fractures in the column bases. The Erie removed the roller nests and replaced them with bronze-surfaced steel slide bearing plates. Many of the original iron bearing plates embedded in the masonry below the column feet were replaced with larger ones for better weight distribution, and the original shoes and new plates were welded together.[38]

The original longitudinal struts had been fastened to the columns by angle braces bolted to the strut top and bottom flanges, and those connections had become badly worn. In 1944, the Erie removed and replaced the longitudinal and transverse struts with new ones of larger dimensions to resist buckling and vibration (See figures 25 and 26). This work did not include longitudinal struts already replaced at the bottom of tower B in 1908 and towers D and E in 1911. All new longitudinal and some lower transverse struts were built up from riveted angles with laced tops and bottoms and deeper, latticed sides, and riveted to the columns. The new second and third transverse struts below the top strut were built of opposed C-channel sides with laced tops and bottoms. The ends of each strut incorporated gusset plates with horizontal pins for the new diagonal rod bracing. The weakness of the tower column joints and inadequacy of the diagonal bracing were such that a temporary strut had to be installed before each old one could be removed and replaced in order to conduct the work without interrupting rail traffic over the bridge. At the bottoms of the towers, the original 1875 transverse struts with their tensioning block mechanisms were retained. As part of the work on towers D and E, the 1875 intermediate longitudinal struts located between the transverse struts in the panel at the bottoms of the towers and the vertical central post connecting those intermediate transverse struts were removed.[39]

The original paired diagonal 1¼" diameter X-brace rods in the tower panels were inadequate for the projected loads and were supplemented as part of the 1944 reconditioning (See Figure 27). The Erie added another set of diagonal paired brace rods as the new horizontal struts were installed, doubling the X bracing on the panels of the longitudinal and transverse sides of the towers. The new 1¼" rods were installed between the original ones that were mounted outside the columns by looping them around pins in the end gusset plates in the new struts. Each new double brace rod incorporated four tensioning turnbuckles, two each at the upper and lower ends. Extra pairs of rods were not installed on the transverse sides of towers A and B nor on the west side of Tower F.[40]

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[38] Knowles, "Strengthens Viaduct," 200–202, and "Strengthening Old Viaduct," 774–76.
[39] Knowles, "Strengthens Viaduct," 200–202, and "Strengthening Old Viaduct," 774–76.
[40] Knowles, "Strengthens Viaduct," 202, and "Strengthening Old Viaduct," 776.

The 1943–44 reconditioning project required 275 tons of steel, which had to be approved as a wartime necessity by the U.S. government. The project began on August 9, 1943, and was completed on September 10, 1944 (See Figure 28). Materials were delivered over the Pennsylvania Railroad Buffalo Division's Rochester Branch, which ran under the viaduct on the east bank of the Genesee River. The new longitudinal and transverse struts were hoisted from erection trusses cantilevered off the tops of the towers using cable hoists located on the ground below. The Erie Railroad's own engineers designed the reconditioning, and the Erie's own bridge department fabricated the materials and erected them. The project was carried out by J. W. Smith, chief engineer, under the supervision of engineer of structures, A. M. Knowles.[41]

B. Historical Context:

Erie Railroad

The New York & Erie Rail Road was chartered in April 1832 to connect the Hudson River at Piermont, 25 miles north of New York City, with Dunkirk on Lake Erie, 45 miles southwest of Buffalo.[42] "The Erie" was a product of early "railroad fever," championed by citizens of New York State's Southern Tier as a New York City–Great Lakes through route for trade that could compete with the parallel Erie Canal to the north and serve as an outlet for goods produced in the interior. It was one of the first U.S. railroads conceived as a single long regional connecting system. Construction began in 1836, and the first train ran over the line on April 22, 1851. According to its 1832 charter, the New York and Erie Rail Road track gauge was set at 6', which Erie President Eleazar Lord and associates believed was safer and more efficient than the 4'-8½" wide standard gauge.[43] That soon proved a poor choice, as shifting freight or cars to railroads of different gauges at freight termini proved costly and inefficient.[44] The New York & Erie's main line was an engineering feat incorporating massive cuts, fills, retaining walls, and landmark bridges. The best known is Julius Adams and James P. Kirkwood's 1848 Starrucca Viaduct at Lanesboro, Pennsylvania (HAER PA-6). Still in service, this 1,040'-long, 90'-high, seventeen-span viaduct built of locally-quarried sandstone was declared a National Historic Civil Engineering Landmark in 1973. East of the Starrucca Viaduct and less well known was a 275'-long timber-arch bridge soaring 175' over Cascade Creek (See Figure 29). Built in 1843 by Julius

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[41] Knowles, "Strengthens Viaduct," 200–202, and "Strengthening Old Viaduct," 774–76. The 1943–44 project is documented in a set of engineering plans titled Erie Railroad Co., Buffalo Division, Bridge 361.66 (Portage Viaduct), Reconditioning Towers, Office of Engineer of Structures, var. dates, 1943–44, in the Bridge (BR) 361.66 plan archives of Norfolk Southern Corporation / Norfolk Southern Railway.
[42] Bruce Seely, "Erie Railway," HAER NY-124, Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, 1977, 3. This narrative provides a history and description of the Erie.
[43] H. Roger Grant, *Erie Lackawanna: Death of an American Railroad, 1938–1992* (Stanford, CA: Stanford University Press, 1994), 1–2.
[44] William Doyle, personal communication with the author, June 2015.

Adams and once the longest single-span wood bridge in the United States, it had been replaced by a massive fill embankment by 1860 (HAER PA-18).[45]

By the time the New York & Erie Rail Road was completed in 1851, its original chartered New York state termini—Piermont at its east end and Dunkirk at its west—had faded in importance, so the Erie sought improved strategic regional connections at both ends. To the east, the Erie acquired the connecting Paterson & Ramapo and Paterson & Hudson rail lines in bordering New Jersey in 1852, gaining direct rail access to the Jersey City docks directly opposite lower Manhattan. To the west, Buffalo had become a superior destination compared to Dunkirk, as it was the western trade terminus of the Erie Canal and a key transportation gateway to the Great Lakes and Canada.[46]

The history of the establishment of what eventually became the Erie's Buffalo Division between Buffalo and Hornell, New York crossing the Genesee River at Portage is convoluted even by most railroad corporate history standards. The following simplification presents key points. The Attica & Hornellsville Railroad Company incorporated in May 1845 and in 1851 changed its name to the Buffalo & New York City (B&NYC). The first segment of the B&NYC to open was Hornellsville to Portage in January 1852. The Portage to Attica segment was completed that July. The B&NYC acquired preexisting track between Attica and Depew from the Buffalo & Rochester Railroad and built the final 8-mile segment connecting Depew and downtown Buffalo in October 1852. The Buffalo, New York & Erie Railroad Company (BNY&E) incorporated in 1857 and took over the B&NYC but through service was limited by ongoing litigation. The BNY&E forced the New York & Erie Rail Road (NY&E) to operate its through service via its longer and slower route from Corning to Buffalo via Avon, Batavia, and Attica. In 1861 the NY&E became the Erie Railway Company. Shortly before, the NY&E's receiver had acquired the B&NYC's Attica-Hornell line, which was turned over to a temporary company, the Buffalo Branch of the Erie Railway. The Erie Railway was granted trackage rights west of Attica to reach Buffalo. In 1863, the Erie Railway leased the BNY&E, finally gaining control of the entire line from Hornell to Buffalo.[47]

This complex corporate evolution ultimately gave the Erie a dedicated connection between the New York City area and Buffalo. The Hornell–Buffalo route quickly made the Erie a major grain, produce, livestock, and lumber hauler. In 1875 the Erie Railway declared bankruptcy in the wake of the Panic of 1873 and reorganized as the New York, Lake Erie & Western (NYLE&W) Railroad Company in 1878. The NYLE&W continued expanding westward from Hornellsville via Salamanca, eventually reaching Chicago through lease of the New York, Pennsylvania & Ohio Railroad between Salamanca, New York, and Marion, Ohio; and

[45] Julius Adams, "The Starrucca Viaduct, on the N.Y., L.E, & W. Railway," *Engineering News and American Railway Journal* 20 (September 1, 1888): 160; Seely, "Erie Railway," 13–15.
[46] Seely, "Erie Railway," 19–21.
[47] George H. Minor, *The Erie System: A Statement of Various Facts Relating to the Organization and Corporate History of the Various Companies Which Either Directly or Indirectly Are Now or Have Heretofore Been Owned, Leased, Operated or Controlled by Erie Railroad Company and Its Predecessor Companies*, 2nd ed. (New York: Erie Railroad Co., 1936), 174–79; William D. Burt, personal communication with the author, December 2018.

construction of the Chicago & Atlantic Railway between Marion and Hammond, Indiana, by 1883. The Erie covered the final 20 miles west to Chicago via the Chicago & Western Indiana Terminal Railroad.[48]

In 1880 the NYLE&W undertook important system-wide track improvements. In the late 1870s it was still running on 6' (wide) gauge rails. After reorganization in 1878, the NYLE&W decided to convert its track to 4'-8½" (standard) gauge, a process they completed in phases over several years. By late that year, the NYLE&W had almost completed double-tracking the Buffalo Division except for 3 miles west of the Portage Viaduct in Genesee Falls where the railroad chose to realign the roadbed. The original 1852 track alignment came off the west end of the viaduct at an elevation of 1,300', curved north into a deep, narrow, single track cut through unstable soil, and straightened out in an undulating-profile tangent, leveling off at an elevation of 1,380' south of Castile. Westbound trains had to proceed slowly across Portage Viaduct and often stalled on the 53'-per-mile grade, requiring additional locomotives to push them up the hill toward Castile. In late 1880 the NYLE&W hired 300 men to construct a new, wider double-track alignment that curved more sharply north off the west end of the viaduct, and ascended the hill on a constant 32'-per-mile grade in a sweeping S-curve before crossing over and rejoining the original track alignment (See Figure 30). When completed in 1881, the Genesee Falls relocation allowed trains a third longer than before to climb the hill. This project completed the important double-tracking project between Jersey City and Buffalo, except for the Portage Viaduct itself, which remained a short single-track bottleneck.[49]

New York, Lake Erie & Western Railroad traffic got a boost in 1889 with completion of the Central New England Railway's massive Poughkeepsie Railroad Bridge over the Hudson River (HAER NY-131). This bridge gave the Erie a direct New England freight connection at the Maybrook Freight Yard in Orange County, New York, via what became known as the New York, New Haven & Hartford Railroad's Maybrook Division. After the NYLE&W declared bankruptcy in the wake of the panic of 1893 and reorganized as the Erie Railroad in 1895, it became a major coal hauler and serious competitor to the New York Central and Pennsylvania railroads for Chicago–New York City area freight.[50] However, the Erie faced physical plant challenges at the start of the twentieth century. Its New Jersey–Chicago route was curvy and hilly, and longer than the New York Central and the Pennsylvania railroads' routes. The Erie needed to keep pace with its competitors by initiating the kind of track curvature and gradient reduction cutoff projects to increase efficiency that many U.S. railroads were undertaking in the turn-of-the-century railroad "Era of Improvements."[51]

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[48] Seely, "Erie Railway," 19-23; Burt, personal communication with the author, December 2018; Doyle, personal communication with the author, June 2015.
[49] William D. Burt, unpublished manuscript, 2017, 9–10. No information was found in the historical record to indicate whether the Erie and Morison factored the gauge change into the Portage Viaduct design.
[50] Grant, *Erie Lackawanna*, 6.
[51] Seely, "Erie Railway," 25–26.

In 1901 Frederick Underwood took over as Erie Railroad president, a position he held until 1927. Underwood oversaw $174 million in improvements that turned the Erie into a modern railroad. Improvement projects included hundreds of miles of extensive rail line reconstruction, realignment, grade reduction, and double-tracking between Chicago and New Jersey. The Erie moved more freight tonnage per train with greater efficiency. Between 1901 and 1926, costs fell 11 percent, traffic increased from 4.77 to 9.46 billion ton-miles, and revenues increased from $40 million to $118.5 million.[52] The Erie purchased many new, heavy 2-8-0 wheel-arrangement Consolidation-type steam locomotives.[53] Increased freight traffic speed, weight, and volume prompted the Erie to replace the Portage Viaduct's 1875 truss spans at the start of this period of improvements.[54]

In 1926 the Erie came under control of the Van Sweringen brothers' rail system, which included the Chesapeake & Ohio Railroad and the Nickel Plate Road. Erie presidents John J. Barnet and Charles Denney made additional improvements, including new mechanical systems, heavier rail, longer sidings, and new signals, and purchased new, heavy 2-8-4 wheel-arrangement Berkshire steam locomotives. In 1938 the Erie was one of the 31 percent of U.S. railroads in bankruptcy; however, World War II soon revived rail traffic, and Erie freight revenues increased through 1945. In 1939 the Erie tested new General Motors diesel-electric locomotives, which demonstrated superior power and efficiency compared to Erie steam locomotives. The Erie took delivery of its first diesels for use on long-distance main line freight trains in October 1944. Associated steam locomotive reassignments prompted the 1943–44 Portage Viaduct tower reconditioning project. By 1954 steam locomotives were gone from the Erie.[55]

In 1960, the Erie Railroad merged with its parallel New Jersey–Buffalo rival Delaware, Lackawanna & Western Railroad to form the Erie-Lackawanna Railroad. The Erie-Lackawanna partnership briefly benefited from redundant track elimination and the strong Vietnam War–era economy. The Erie-Lackawanna Railroad's assets were acquired by the newly-created Erie-Lackawanna Railway in 1968, and that line declared bankruptcy in 1972.[56] As late as 1967, they ran four daily eastbound freight trains from Chicago to Jersey City/Croxton Yard at Secaucus, New Jersey, and four from Chicago to Maybrook, New York, bound for New England via the Poughkeepsie River Bridge.[57] That bridge burned in 1974, significantly impacting Erie-Lackawanna Railway and other rail traffic in the region. The Erie-Lackawanna system, including the Buffalo Division, became part of Conrail in 1976, and the Buffalo Division became part of Norfolk Southern Railway's Southern Tier Line in 1999.

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[52] Seely, "Erie Railway," 27.
[53] Frederick Westing and Alvin F. Staufer, *Erie Power: Steam and Diesel Locomotives of the Erie Railroad from 1840 to 1970* (Medina, OH: Alvin F. Staufer, 1970), 94-95.
[54] Knowles, "Strengthens Viaduct," 199–200; Erie, "Portage Viaduct Strengthened and Reopened,"; Seely, "Erie Railway, 27-34.
[55] Seely, "Erie Railway," 38–44.
[56] Seely, "Erie Railway," 47.
[57] Erie Lackawanna Railroad Company, "Through Freight Train Classifications, Times and Connections, Effective April 30, 1967."

1852 Portage Trestle

The meandering Genesee River, which flows north from Northern Pennsylvania through Western New York State to its Lake Ontario outlet at Rochester, proved a significant geographical barrier to straight-line railroad construction between Hornell and Buffalo in the mid-nineteenth century. The 1852 Portage trestle and its 1875 Portage Viaduct successor were sited at a strategic location at the westernmost bend in the Genesee River, at a distinct elbow marking the transition from the deep, broad river valley lying to the southeast to the 17-mile-long Genesee River Gorge extending to the northeast. Correspondingly, this river crossing point at the head of the gorge is a distinct elbow in the Hornell-Buffalo railroad route, with a relatively flat eastern approach through Portage to the gorge, and a steeper grade extending north through Genesee Falls to Castile. The Attica & Hornellsville Railroad's surveyors solved the problem of crossing the Genesee River Valley by choosing the crossing point "where the banks were highest and the valley narrowest."[58] The gorge at the Portage railroad bridge crossing is just over 800' wide overall from lip to lip at level ground, 500' wide between its steepest, vertical rock cliffs, and 235' deep from railhead to river bottom. It is important to note that the hamlet of Portageville, after which the Portage Viaduct and its predecessor trestle are sometimes erroneously named, is upstream of the crossing site, which is actually located at the hamlet of Portage, a different and separate location from Portageville.

Construction of the timber trestle began July 1, 1851, and the first train crossed thirteen-and-a-half months later on August 14, 1852. The work progressed from east to west. As each timber bent was built, the trusses were slid out onto the bent and track laid so that a traveling crane could erect the next bent and truss. Fire was naturally a concern, so the bridge was equipped with water tanks and watchmen. The contractors were Lauman, Rockafellow and Moore, who were also the contractors for construction of the rest of the railroad line.[59] Buffalo & New York City Railroad chief engineer Silas Seymour designed the bridge, and civil engineer Lincoln Preston was in charge of construction. The bridge's construction required 1.6 million feet of pine timber cut from 300 acres of adjacent forest, 106,840 lbs. of wrought iron, and 9,200 cubic yards of masonry, and it cost $180,000.[60]

Once completed, the Portage trestle quickly became a major regional tourism attraction. Two new hotels, one named the Cascade House, were built at the east end of the trestle, and the New York & Erie Rail Road advertised special sightseeing excursion trains for visitors to see the structure and the Genesee River Gorge waterfalls.[61] John Abbott, writing in the 1858 *Wonders of the World*, said, "The first and last look at the bridge must be one of dumb amazement. It is the crystal palace of all bridges. How any mortal ever conceived or having conceived, ever dared

[58] "New Portage Viaduct," *Scientific American*, 55.
[59] "'High Bridge,' Portage, New York," *Civil Engineer & Architects Journal* 16, no. 227 (February 1853): 65.
[60] James O. McClure, "The Wooden Viaduct, First to Carry the Erie R.R. over the Genesee River Gorge Just above the Upper Falls at Portage, N.Y.," *Western New Yorker* [Perry, NY], n.d.
[61] Stacia L. Partin, National Register of Historic Places Registration Form, "Letchworth State Park," 2000 (on file at New York Office of Parks, Recreation and Historical Preservation, Peebles Island, Waterford, NY), section 8, pp. 28–29.

carrying it into execution, passes our comprehension."[62] Although the engineering community recognized the trestle was "not notable for the development of any new principle of construction," it was recognized for its size and notoriety.[63] In 1876 *Scientific American* noted that the timber trestle had "obtained world-wide fame" as "one of the boldest and most successful feats of American railroad engineering."[64] Many years later, the Portage timber trestle was still recognized by the engineering community. Bridge engineer Henry Grattan Tyrrell, writing in his 1911 *History of Bridge Engineering*, said, "The most notable of the early [timber trestles] was the old Portage . . . the boldest timber trestle ever built."[65]

The Portage trestle stood for almost twenty-three years until the pre-dawn hours of Thursday, May 6, 1875, when it was destroyed by fire, apparently set alight about 12:50 a.m. by burning embers from an eastbound passenger train. The watchman then on duty discovered the firefighting apparatus was defective and was consequently unable to put out the fire.[66] Eyewitness William Pryor Letchworth, whose Glen Iris estate home still stands at the Genesee River Middle Falls below the trestle, described the nighttime conflagration:

> Every timber in the bridge seemed then to be ignited, and an open network of fire was stretched across the upper end of the valley. Above the bridge, and touching its upper line a black curtain hung down from the sky, its lower edge belted with a murky fringe of fire. The hoarse growl of the flames and crackling of the timbers sounded like a hurricane approaching through the forest. . . . The water in the river was glistening with the bright flare thrown upon it, and the whole valley of the Glen Iris was illuminated in tragic splendor. . . . At fifteen minutes past four the superstructure of the west end of the bridge sank downward and the depression rolled throughout its length to the east end like the sinking of an ocean wave. . . . The whole upper superstructure, including the heavy T rails, went down with a crashing sound so terrible it came to our ears on the wind that it surpassed the roar of the falling avalanches. . . . Timber, rails, bolts, abrading and dislodging burning coals as they fell, crashed downward into indistinguishable ruin.[67]

Immediately after the fire, the Erie Railway was able to quickly reroute its Buffalo Division main line freight and passenger trains over its Rochester Division. This temporarily diverted trains from the main line at Corning (Painted Post), New York, to Avon, and from Avon over the Attica Branch via Batavia, before rejoining the Buffalo Division at Attica.[68] The fire caused considerable local consternation and even some suspicion of arson at the hands of the Erie Railway. Iron bridges had come into favor by the 1870s, and undoubtedly the twenty-two-year-old timber trestle, which required constant maintenance, was facing impending weight capacity limitations. The Erie's expressed desire to replace the timber bridge had been met with local

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[62] Paul Barber, "The Portage Bridge," *Historical Wyoming County* 6, no. 4 (April 1990): 107.
[63] "'High Bridge,' Portage, New York," 65.
[64] "New Portage Viaduct," *Scientific American*, 55.
[65] Henry Grattan Tyrrell, *History of Bridge Engineering* (Chicago: G. B. Williams, 1911), 366.
[66] "The Burning of the Portage Bridge," *Buffalo Courier*, May 8, 1875.
[67] "Burning of the Portage Bridge."
[68] "Erie," *Railroad Gazette* 7 (May 15, 1875): 201.

protest, as the structure was important to the local tourism industry.[69] The Erie spent the two years prior to the fire surveying alternative routes for a new bypass bridge, but with no success.[70] After the trestle burned, some parties reportedly accused the Erie of arson as a convenient method of disposal, claiming as motivations fortuitously low iron prices in the wake of the Panic of 1873 or simply the potential for increased railroad revenue.[71]

1875 Portage Viaduct

On Monday, May 10, 1875, four days after the Portage trestle fire, the Erie Railway awarded a new bridge construction contract to Watson Manufacturing Company with plans drawn up by Erie principal assistant engineer George S. Morison.[72] The Erie required "the work to be finished in 45 days."[73] It is unclear what, if any, plans for the new bridge the Erie might have drawn up before the fire and had at the ready. The swiftness of the award was apparently seen in some quarters as conspiratorial, and Watson was reportedly accused of already having the ironwork ready to go before the fire or for quickly diverting ironwork already fabricated for a bridge project in Africa to win the Portage contract.[74] It is unclear what or whose ironwork was allegedly delivered so swiftly, as the earliest documented ironwork delivery to the construction site was actually not until June 8, twenty-nine days after the contract to Watson had been awarded.[75]

The first Portage Viaduct ironwork was raised June 13, 1875, thirty-four days after the Watson contract was awarded. Erie Railway assistant engineer Andrew Trew supervised the work.[76] The six two-bent towers were erected from temporary timber falsework built on plank floors spanning the stone piers. A 30'-high timber frame was built to erect the bottom section of each tower. The lower iron tower column sections were hoisted and positioned, and the tower iron horizontal struts and diagonal braces were attached. A 55'-tall timber gin pole was then attached to each column, and the plank floor and timber frame were raised to the top of the first section of iron tower columns to erect the second section. The process was repeated until each tower reached its full height. The ends of each column section were fastened by pins and tenon plates. Tower D, one of the two tallest towers, was erected in eleven days. The three long deck trusses were each erected on temporary timber Pratt truss frames assembled on the ground and hoisted into place. Staging was next built on the timber trusses. The iron truss members were brought out from the ends of the bridge and assembled between the temporary timber trusses, which were then lowered back to the ground. The ten 50' girder spans were erected on heavy temporary timbers laid across the tops of each tower.[77]

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[69] Barber, "Portage Bridge," 109.
[70] McClure, "Wooden Viaduct, First to Carry the Erie R.R."
[71] Barber, "Portage Bridge," 109.
[72] Morison, "New Portage Bridge," 1.
[73] "Erie," *Railroad Gazette* 7 (May 15, 1875): 201.
[74] Partin, National Register of Historic Places Registration Form, section 8, p. 30.
[75] Erie Railroad Co., "Portage Bridge 361.66 Buffalo Division," typewritten manuscript, April 9, 1945.
[76] "Portage Bridge," *Cuba (NY) True Patriot*, July 23, 1875.
[77] Morison, "New Portage Bridge," 5–6.

The last truss span ironwork was placed on July 29, 1875, forty-six days after the first column was raised and eighty days after the contract was awarded.[78] The total weight of the finished structural iron was 1.31 million lbs., fastened by 28,000 lbs. of iron hardware.[79] The total cost of the ironwork, including erection, was $87,973, and with the oak timber floor and one coat of paint, the total cost of the bridge above the masonry substructure "did not exceed $95,000, a striking example of the present low prices of iron work and the economy of American skeleton structures."[80]

The first live steam locomotive crossed the bridge at noon on July 31, 1875, forty-eight days after the first ironwork was raised and eighty-two days after the contract was awarded. Erie president Hugh Judge Jewett and his officers watched the first train from the riverbanks below, surrounded by a large crowd of spectators. Newspapers reported varying accounts of the live-load test train sequence, but most noted that at first a single steam locomotive was sent across, then a pair, and then six, all stopping for load tests, followed by a series of increasingly heavy freight, and then press and excursion trains.[81] One account stated that George Morison rode the test locomotives. When the set of six locomotives stopped at the center of the 118' truss, the 800-ton weight, more than twice the design load, resulted in less than 5/8" deflection.[82]

The eighty-six-day elapsed time between the Portage trestle fire and placement in service of the Portage Viaduct seems remarkably short by today's standards; however, examination of project milestones shows the elapsed time for actual ironwork construction was much shorter (forty-six days), and the start of construction was actually delayed by thirty-four days. The Erie Railway's forty-five-day Portage contract completion time frame was apparently not an unusual request, at least between the Erie and Watson, which had just completed a major bridge replacement project for the Erie in under forty days. In March 1875, three spans of the Erie's massive five-span Mill Rift, Pennsylvania, bridge over the Delaware River and Delaware & Hudson Canal just west of Port Jervis, New York, had been destroyed in a spring flood "ice gorge," putting the Erie's main line out of service. The Erie contracted with the Watson Manufacturing Company to erect a temporary bridge and to replace the destroyed one with iron Post trusses, three of them just over 150' long. According to the contract, the first span was "to be finished 15 days from the signing of the contract and the other two each within six days thereafter, giving 27 days in all. The price is $70,000 cash."[83] After construction, another periodical article about the Mill Rift Bridge project reported that "the Watson Manufacturing Company had the iron work all completed within the extremely short time allowed by the contracts."[84] Watson's 1875 Mill Rift Bridge was replaced by a steel pin-connected Pratt deck truss structure (Delaware River Bridge [Bridge 90.84], HAER PA-23) in 1895.[85]

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78 "Portage Bridge," *Cuba True Patriot*.
79 "New Portage Viaduct," *Scientific American*, 55.
80 Morison, "New Portage Bridge," 8.
81 "The New Iron Bridge at Portage," *New York Times*, August 1, 1875.
82 "The New Portage Bridge: The Longest, Tallest and Strongest Railroad Bridge in the World," unannotated newspaper clipping on file at Letchworth State Park.
83 "Erie," *Railroad Gazette*, March 27, 1875, 127.
84 "Erie," *Railway Times*, May 29, 1875, 529.
85 Seely, "Erie Railway," 66.

The matter of the Portage Viaduct ironwork procurement delays is curious, and sources contain conflicting information. The Watson Manufacturing Company was awarded the Portage contract on May 10, 1875. It is unclear when or how quickly Watson actually began fabricating bridge parts for the Portage contract, but ironwork from one or more sources reportedly began arriving on the construction site on June 8, twenty-nine days after the contract to Watson was awarded.[86] Construction did not start until June 13, five days later. Sources indicate possible multiple suppliers for the fabricated ironwork and they may have made late deliveries, and there was also a series of fires at the Watson shops in June 1875 that may have slowed delivery. The first Watson fire, a suspected arson, broke out in a lumber storage shed on June 11.[87] The second fire, much larger and more damaging and also a suspected arson, broke out at Watson's on June 29, sixteen days after the Portage construction reportedly started. The *Paterson Daily Press* reported that "regarding the contracts now under way by the firm, that of the Portage bridge will not be injured in the least, as they expect to begin work on it by to-morrow."[88] It is unclear if that meant starting the company's very first work on the Portage contract or resuming interrupted work already in progress. The following day, June 30, the *Paterson Daily Press* reported that "the Erie authorities have given the Watsons until July 12th, an extension of nearly two weeks, to complete Portage bridge. It will doubtless be finished next week."[89] It was actually completed twenty-nine days later and placed in service after two more. On July 14, two weeks later, the same newspaper reported that "some alterations having been made in the specifications of the Portage bridge, which is to be heavier than originally designed, that structure is not yet finished, but will be this week. To date, 1,170,000 pounds of iron have been shipped to Portage for this bridge."[90] It was actually finished two weeks and a day later. That ironwork weight figure would mean that by July 14, thirty-six days after the Watson contract was awarded, 90 percent of the total reported weight of 1.31 million lbs. of ironwork had been shipped, and presumably fabricated, by Watson.[91]

Sources contain contradictory information about the number of ironwork suppliers. On June 11, thirty-two days after the Watson contract was awarded, the *Castilian* newspaper reported that some of the Portage Viaduct ironwork was being fabricated by an "Elmira [New York] rolling mill," and that there were also delays in obtaining stone for the substructure.[92] According to George Morison, some of the iron was supplied by a source in Pittsburgh.[93] Morison stated: "The iron work was considerably delayed by failures of the rolling mills to make prompt delivery, and the first iron column was not raised until June 13."[94] Fellow bridge engineer Charles Macdonald took Morison and the Erie Railway to task for the long elapsed time between the award of the Portage contract and project completion. Macdonald said they should have used "sections and

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[86] Erie Railroad, "Portage Bridge 361.66 Buffalo Division."
[87] "Fire at the Watsons This Morning," *Paterson Weekly Press*, June 11, 1875.
[88] "Partial Destruction of the Watson Bridge Works," *Paterson Daily Press*, June 29, 1875, 3.
[89] "The Fire at the Watsons," *Paterson Daily Press*, June 30, 1875, 3.
[90] "The Watson Bridge Works," *Paterson Daily Press*, July 14, 1875.
[91] "New Portage Viaduct," *Scientific American*, 55.
[92] "Portage Bridge," *Castilian* [Castile, NY], Friday, June 11, 1875.
[93] Charles Macdonald, "On the New Portage Bridge," *Transactions of the American Society of Civil Engineers* 5 (February 1876): 239.
[94] Morison, "New Portage Bridge," 2.

shapes of iron which could most readily be combined into the required members," recommending more "well-known" members such as Phoenix columns and lattice trusses. Macdonald claimed that the suppliers "were not familiar with the details of a trestle of this magnitude" and noted "a large portion of the material was procured from rolling mills several hundred miles distant" as another disadvantage.[95] Macdonald's criticisms suggest multiple ironwork contributors. Morison, admitting the contracting method was not ideal for rapid completion, replied, "The true method of letting the contract would have been to give the work to three builders, all work to be done by the pound; the towers east of the main channel should have been given to one party, those west of that channel to a second, and the superstructure to a third. Had this been done, construction would have taken 45 days." This suggests there was only one ironwork supplier. Morison credited the awarded contractors (Watson) with the recent forty-day completion of the Mill Rift Bridge, stating that Watson was competent to have accomplished the Portage Viaduct in sixty days, "though they could not have done much better." According to Morison, the "radical mistake" was ordering three-quarters of the iron from a Pittsburgh mill that failed to deliver in time. Morison also noted another factor, that twenty days after the timber trestle fire, the Erie Railway went into receivership, generating supplier fears about payment and leading to ironwork delivery delays.[96]

Beton Coignet

The Erie Railway was a pioneer in the use of concrete in the 1870s. In the 1860s, French engineer François Coignet promoted his patented *beton coignet* (Coignet concrete) in France. Octave Chanute was an early champion of this material in the United States.[97] Chanute said the patented proportioned mixture of hydraulic cement, sand, and water "forms a plastic mass, capable of being rammed into crevices of all masonry, of being molded to all shapes, and made into monoliths of all kinds of sizes, from a statue or obelisk to a culvert or viaduct. When set it becomes a hard and imperishable stone . . . about as strong as good granite."[98] In 1870, John H. Goodrich Jr., who held the U.S. rights to Coignet's patents, established the New York & Long Island Coignet Stone Company of Brooklyn, New York (later the New York Stone Contracting Company). Octave Chanute suggested to George Morison in 1875 that he repair some of the fire-damaged 1852 timber trestle's stone piers at the Portage Viaduct with a layer of *beton coignet*. The New York & Long Island Coignet Stone Company covered the upper surfaces of the piers to prevent water infiltration. For the river piers, they encased the upstream cutwaters and built wooden cribs around the submerged portions and filled them with *beton coignet* rammed into the piers and the bedrock river bottom's cavities. Chanute reported that these repairs cost $6,000, versus the $40,000 estimate to rebuild the river piers with new stone. In 1880, New York, Lake Erie & Western Railroad engineers noticed that the crest of the Genesee River Upper Falls was receding at an alarming rate of about 15' a year and had advanced over 240' toward the viaduct in

[95] Macdonald, "On the New Portage Bridge," 236–37.
[96] Macdonald, "On the New Portage Bridge," 239.
[97] Carl Condit, *American Building Art: The Nineteenth Century* (New York: Oxford University Press, 1960), 227; Simine Short, personal communication with the author, May 2015.
[98] Octave Chanute, "Repairs of Masonry," *Transactions of the American Society of Civil Engineers* 10 (September 1881): 292.

the thirty years since the 1852 timber trestle was completed, reaching a distance of 119' from the nearest bridge pier. In the summer of 1881 the Erie applied a *beton coignet* layer to the riverbed and built a 210'-long, 3'-high *beton* dam to divert water from the worst eroding area at the falls. This was reportedly the first time the material had been employed in this manner. The Erie Railroad continued the practice of reinforcing the riverbed and banks with concrete to prevent erosion into the early twentieth century. Octave Chanute touted multiple examples of the Erie's concrete repairs, including relining thirteen culverts (1,115' of culvert) on the Buffalo Division and a portion of the 4,316'-long Bergen (New Jersey) Tunnel.[99]

In 1958 the Erie Railroad used concrete at the Portage Viaduct again in a major project that ended up affecting the appearance of the Genesee River Gorge at the viaduct. Falling rocks from ongoing erosion of the west bank sandstone cliffs were threatening the towers and piers below. The Erie paid Penetryn Systems Inc. of Albany, New York, $126,000 to install their patented stabilization system and materials. Penetryn removed loose rock, drilled holes in the cliff, and pumped concrete grout into the holes to fill cracks and bond the stones together. They then installed a network of rebar and wire mesh across the cliff face and filled it with a 9"-thick layer of concrete to reinforce the cliff face.[100]

Design Attribution

Some popular interpretations of Portage Viaduct's history attribute its design to Erie Railway chief engineer Octave Chanute, although George Morison is more generally credited. Chanute was an important nineteenth-century engineer and Erie Railway engineering figure in his own right and was involved in bridge design and developing specifications with Morison.

Octave Chanute (1832–1910) was born in Paris, France, and came to New York City via Louisiana as a child. He was made a surveyor on the Hudson River Railroad at age 17 and was promoted to division engineer after four years. Between 1853 and 1873, Chanute was chief engineer for several midwestern U.S. railroads and designed stockyards in Chicago. In 1867, Chanute undertook his first major bridge project, the first bridge over the Missouri River at Kansas City, Missouri, which was over a mile long and included a 363' swing span. It was on this project that Chanute first met George S. Morison and hired him as an assistant. In March 1873 Chanute accepted the position of chief engineer with the Erie Railway and brought Morison along with him as resident engineer. The Erie promoted Chanute to assistant general superintendent in the fall of 1875, after completion of the Portage Viaduct. Chanute developed influential railroad technology on the Erie, including the "Chanute head" rail, "fish-plate" rail joint bars, fixed signals, and tie date spikes and S-clamps. He developed methods of railroad tie

[99] Simine Short, *Locomotive to Aeromotive: Octave Chanute and the Transportation Revolution* (Urbana: University of Illinois Press, 2011), 90; Chanute, "Repairs of Masonry," 293–98, 305-6; "The Great Portage Bridge—Protecting It from the River—Successful Engineering," *Buffalo Express*, November 11, 1881; "New and Old Erie Bridges," *Erie Railroad Employees Magazine*, July 1906, 212; Seely, "Erie Railway," 50.
[100] Erie Railroad, "Erie Spends $126,000 on Cliff to Keep Portage Span Safe: Concrete and Steel Coat Protects Rock Face," *Erie Railroad Magazine*, October 1958, 8–9, 27.

preservation and operated several tie preservative plants. Chanute was also instrumental in adoption of the 2-8-0 wheel arrangement Consolidation-type steam locomotive on the Erie. Chanute's last major project for the Erie, and his biggest bridge, was the 1882 Kinzua Viaduct (HAER PA-7) near Alton, Pennsylvania, on the Erie's Bradford Division, built to reach western Pennsylvania coal, oil, and timber resources. Chanute designed the Kinzua Viaduct in collaboration with A. Bonzano and Thomas C. Clarke of Clarke, Reeves & Company of the Phoenix Iron Works, Phoenixville, Pennsylvania. (This became the Phoenix Bridge Company in 1884.) The wrought-iron viaduct, built between May 10 and August 29, 1882, was 302' high and 2,052' long, with Phoenix columns supporting continuous Howe trusses. An Elmira Bridge Company steel deck-girder span replaced it in 1900.[101] Kinzua was "America's greatest iron viaduct . . . for a short time the highest bridge in the world."[102] Chanute resigned from the Erie in September 1883 and became a private engineering consultant in Kansas City, Missouri. Chanute's later bridges included the Missouri River crossing at Sibley, Missouri, and the Mississippi River bridge at Fort Madison, Iowa. Chanute was elected president of the American Society of Civil Engineers in 1891. He eventually moved to Chicago and became an authority on the growing field of aeronautical engineering, collaborating with the Wright brothers in the late 1890s.[103]

Shortly after Chanute became chief engineer of the Erie Railway in 1873, he promoted George Morison to principal assistant engineer.[104] Morison credited himself with design and construction of the Portage Viaduct, writing in a paper presented to the ASCE on November 27, 1875, that the bridge was "built according to plans prepared by and under the direction of the writer."[105] In J. E. Greiner's "The American Railroad Viaduct: Its Originals and Evolution," Morison said of the Portage Viaduct, "This was designed by myself and built under my direction."[106] After Morison's death in 1903, a memoir prepared by the American Society of Civil Engineers stated "he designed and built the iron structure." One of that memoir's authors, Charles Conrad Schneider, was the Erie Railway's chief draftsman and worked closely with Morison during the 1873–75 period of Erie bridge specifications development and Portage Viaduct design.[107]

A later authority, Erie Railroad engineer of structures A. M. Knowles, wrote in 1944: "This viaduct was built under the direction of Octave Chanute, Chief Engineer of the Railway, while Geo. S. Morison, C.E. designed the viaduct."[108] Octave Chanute biographer Simine Short assigns

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[101] Frank Griggs, "Great Achievements: Notable Structural Engineers: Octave Chanute," *Structure Magazine*, March 2007, 58-59; Petroski, *Engineers of Dreams*, 93; Short, *Locomotive to Automotive*, 2, 50, 58, 83, 86, 93, 101, 139, 150
[102] David Plowden, *Bridges: The Spans of North America*, 2nd rev. ed. (New York: W. W. Norton, 2002), 74.
[103] Griggs, "Octave Chanute," 59.
[104] Gerber, Prout, and Schneider, "Memoir of George Shattuck Morison," 514.
[105] Morison, "New Portage Bridge," 1.
[106] Greiner, "American Railroad Viaduct," 360.
[107] Gerber, Prout, and Schneider, "Memoir of George Shattuck Morison," 514.
[108] A. M. Knowles, "Erie Railroad Company, Portage Viaduct over the Genesee River Gorge, Portage, NY, 1852–1944," typewritten manuscript, September 10, 1944, 2.

the Portage design credit to Chanute, which she says he then passed on to Morison, perhaps to shield himself from liability:

> almost all documents [reports] are written up by Morison. Chanute firmly believed that the new Resident Engineer of any of the bridges that he was involved with should receive full credit, even though he worked closely with that person and probably did most of the design work. OC [Chanute] usually stated that a bridge was designed by the engineers of the Erie (or whichever company he worked for at that time). He learned his lesson in the 1860s when he let his resident engineer go on his own to design a bridge; it collapsed late during the construction, killing a few workers.[109]

Bridge engineering historian Frank Griggs Jr., author of biographies of Chanute, Morison, Schneider, and other important bridge engineers, said about Chanute and the Kinzua Viaduct: "As with the Portage Bridge, it is not known how much of the actual design Chanute was involved with. However, as Chief Engineer, he had the final say on design and construction."[110] Regarding the Portage Viaduct, Griggs stated, "It appears from the record that Morison took the lead in designing and supervising the construction of an iron replacement span."[111] It is Griggs's conclusion that the Portage design "was Morison with little or no input from Chanute but with the assistance of Schneider."[112]

1903 Strengthening

In 1903 the Erie Railroad undertook its first round of major improvements to the Portage Viaduct. The structure had served the Erie Railway and successors New York, Lake Erie & Western Railroad (1878) and Erie Railroad (1895) adequately until about 1900. A 1903 engineering periodical stated: "As the traffic of the road increased in weight and volume, and the iron spans became inadequate, plans were made for replacing them with heavy riveted trusses and plate-girder spans for increasing traffic at a higher speed."[113] A. M. Knowles, writing in 1944, said "By 1903 the weight of engines and cars had increased to such an extent that the iron spans became inadequate and they were replaced by the steel spans now in service."[114] It is likely that by 1903 the original wrought-iron deck truss spans were weakened and exhibiting wear in the pinned joints between truss members. The Erie may have had concerns about fatigue and cracking in the joints and wrought-iron members.[115] Clearly the spans had become inadequate and replacements became necessary. The Erie drew up plans for an entirely new, double-track viaduct in 1902 (See Figure 31).[116] Plans show a viaduct with shorter overall length and only five

[109] Short, personal communication with the author, May 2015.
[110] Griggs, "Octave Chanute," 59.
[111] Griggs, "Geo. S. Morison, Ch. Eng'r," 15.
[112] Griggs, personal communication with the author, 2019.
[113] "New Spans of the Portage Viaduct, Erie R.R.," 120.
[114] Erie Railroad, "Portage Viaduct Strengthened and Reopened."
[115] Howard Swanson, Norfolk Southern Railway assistant chief engineer, personal communication with the author, January 2019.
[116] "Another Bridge over Portage," *Democrat and Chronicle* [Rochester, NY], March 22, 1902.

towers, accomplished by filled approaches with taller abutments. The plans indicated transverse-battered profile towers with tall square-proportioned panels with transverse and longitudinal struts and diagonal bracing, carrying a continuous line of four parallel shallow Warren deck trusses. The Erie did not build that new viaduct, but plans show that it would have been located just south of the existing structure (See Figure 32).[117] Because George S. Morison designed the 1875 Portage Viaduct in anticipation of double-tracking and associated added weight on its towers, it did not need to be entirely replaced in 1903. Instead, the Erie chose to replace the inadequate original wrought-iron Pratt deck trusses with three long riveted steel, pin-connected Pratt deck trusses and ten 50' deck girder approach and tower spans.[118]

The 1903 Portage Viaduct truss replacement project occurred during the early twentieth-century U.S. railroad "Era of Improvements," which lasted until about 1917. By the end of the nineteenth century, U.S. railroads had largely stopped seeking profits by building new lines to tap new markets and were instead focusing on upgrading existing lines and reducing grades and curves, sometimes through line relocations, in order to reduce operating costs and move goods to market cheaper and faster than their competitors.[119] Perhaps the most impressive and well-known project of this type was the Erie competitor Lackawanna Railroad's pre–World War I New Jersey and Nicholson cutoff projects. These projects included massive cuts and fills and landmark tunnels and viaducts, among them Tunkhannock Viaduct at Nicholson, Pennsylvania (HAER PA-87), still the world's largest concrete arch bridge.[120]

The Erie Railroad undertook major "Era of Improvement" projects after 1901, when financier J. P. Morgan invited Frederick D. Underwood, an experienced railroad executive previously with the Chicago, Milwaukee, St. Paul & Pacific, Soo Line, and Baltimore & Ohio railroads, to take over as Erie Railroad president, a position he held until 1927. Fourth Vice President for Engineering and Construction Joseph Marshall Graham assisted him.[121] According to Underwood, by 1916, just before U.S. entry into World War I, the Erie had constructed just over 600 miles of new and rebuilt track between Jersey City and Hammond, Indiana.[122] Erie improvement projects included 814 new bridges, increasing its bridge-carrying capacity by 31 percent.[123] The Erie's pre–World War I improvements under Underwood included major line relocation "cutoff" projects, notably the 38.6-mile Erie & Jersey Railroad ("Graham Line") between Guymard (Graham) and Highland Mills, New York, and the 32.6-mile Genesee River Railroad ("River Line") between Cuba and Hunts, New York, just a few miles east of the Portage

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[117] Erie Railroad Co., Buffalo Division, Portage, Proposed New Viaduct and Revision of Alignment & Grades, July 1902, Drawing No. MF225275 BR 361.66.
[118] Knowles, "Strengthens Viaduct," 199 and "Strengthening Old Viaduct," 773; "New Spans of the Portage Viaduct, Erie R.R.," 120.
[119] William D. Burt, "Erie's River Line, Part 2: Leap for the Brass Ring," *Diamond* 5, no. 2 (1990): 5-6; Steven Usselman, *Regulating Railroad Innovation: Business, Technology and Politics in America, 1840-1920* (New York: Cambridge University Press, 2002), 182.
[120] Thomas T. Taber and Thomas T. Taber III, *The Delaware, Lackawanna & Western Railroad in the Twentieth Century, 1899-1960,* vol. 1 (n.p., 1980), 34-47.
[121] Burt, "Erie's River Line," 5-7; Seeley "Erie Railway," 27–29.
[122] *Railway Review* 75, September 20, 1924, 423-430.
[123] Grant, *Erie Lackawanna*, 8–9.

Viaduct, as well as the 13.2-mile Columbus & Erie Railroad between Niobe Junction, New York and Columbus, Pennsylvania.[124] These cutoff projects included several landmark Erie steel viaducts: the Graham Line includes the 200'-high, 3,200'-long Moodna Viaduct (HAER NY-62; the Erie's longest bridge), and the 72'-high, 590'-long Woodbury (Bonny Brook) Viaduct, both built 1906–9 and still in service. The Genesee River Line included the 150'-high, 1,920'-long Rush Creek (Fillmore) Viaduct (HAER NY-42) and the 144'-high, 3,120'-long Genesee River (Belfast) Viaduct (HAER NY-43), both built in 1908 and dismantled by Conrail in 1980–81. All four viaducts were designed under Erie engineer of bridges and buildings Mason R. Strong.[125]

The Erie's projects also addressed the need to accommodate the rapidly increasing weight of locomotives and rolling stock and longer, heavier, faster trains over existing, decades-old structures like the 1875 Portage Viaduct. The Erie's 1903 project to replace the viaduct's inadequate original wrought-iron trusses with steel truss and girder spans was undertaken to accommodate the new, heavier Erie steam locomotives, in particular, large orders of heavy 2-8-0 Consolidation locomotives. The Pennsylvania Railroad introduced the Consolidation locomotive in the 1870s, and it quickly became their standard freight locomotive type. Its popularity spread quickly, and the Consolidation "became the most popular type of freight locomotive in the United States…and was built in greater quantities than any other single wheel arrangement."[126] Erie Railway chief engineer Octave Chanute observed Consolidations at work on the Baltimore & Ohio Railroad and championed their adoption by the Erie.[127] The Erie ordered its first Consolidations in 1877 and eventually purchased roughly 1,000 from multiple locomotive builders.[128]

According to Board of Railroad Commissioners of New York bridge ratings published in 1891, Portage Viaduct's 118'- and 100'-long wrought-iron Pratt deck trusses were then rated for a moving load of two coupled Erie Consolidation locomotives followed by a train load of 3,000 lbs. per foot. The 50' approach and tower truss spans were rated for one Erie Consolidation.[129] In 1891, the Erie's heaviest Consolidations, the H-8 class built in 1888, weighed 115,850 lbs. on their driving wheels ("drivers") and 131,150 lbs. overall (on drivers and leading truck), not including their coal and water tenders.[130] The weight capacity of Portage Viaduct's towers was considered robust at that time. According to the Board of Railroad Commissioners, "The towers are designed to carry, in addition to the weight of a double track superstructure, a moving load of 5,400 pounds per foot. . . . There being undoubtedly such a great excess of strength in these

[124] Burt, "Erie's River Line," 6.
[125] "New and Old Erie Bridges," *Erie Railroad Employees Magazine*, 210.
[126] John H. White Jr., *American Locomotives: An Engineering History, 1830–1880*, rev. and expanded ed. (1968; Baltimore: Johns Hopkins University Press, 1997), 65.
[127] Short, *Locomotive to Aeromotive*, 101.
[128] Westing and Staufer, *Erie Power*, 94-95.
[129] Board of Railroad Commissioners of the State of New York, "Buffalo Div.—Bridge No. 16 over the Genesee River, Portage," in *Strains on Railroad Bridges of the State* (Albany: Weed, Parsons, 1891), 1250–51.
[130] Westing and Staufer, *Erie Power*, 94-95.

towers over present requirements, it is not deemed necessary to tabulate the stresses, etc. in any except the highest and heaviest bent."[131]

The Erie's next order for Consolidations came eleven years later in 1899. These ten H-9 class Consolidations were much heavier than the H-8s, weighing 160,000 lbs. on drivers and 180,000 lbs. without tender. Orders for heavier Consolidations followed quickly, with those built before late 1903 having up to 180,000 lbs. on the drivers and 200,000 lbs. overall weight.[132] This was apparently about the limit of what the Erie could run over its bridges at the time. The Erie was rapidly working to accommodate its new heavier locomotives system-wide, and its annual report for 1901, their first year under president Frederick Underwood, stated:

> On account of the number of heavy Consolidation engines recently bought, and the desirability to run these locomotives over any part of the Erie System, the renewal of bridges has been continued at a rate sufficiently rapid to meet the necessities. In addition to those renewed this year and heretofore mentioned, forty-one bridges are now under construction and will probably be in place before next Winter. Most of these bridges are short spans and inexpensive, but their renewal became necessary on account of the constantly increasing loads carried on locomotives as well as on rolling stock.[133]

The Erie annual report also noted "renewal" of their 302' high, 2,052' long Kinzua Viaduct, which was entirely replaced in 1900. This suggests that the Erie, which had to plan and finance large locomotive orders in advance, was also upgrading its larger, longer bridges in anticipation of the unavoidable weight issues associated with the large orders for new, heavier locomotives (primarily Consolidations).[134] In December 1903, the Erie Railroad began taking delivery of its first truly modern Consolidations, the H-20 class built by the American Locomotive Company (Alco) in Schenectady, New York. Between 1903 and 1910 the Erie purchased a total of 393 of the H-20, -21, and -22 class Consolidations from four different locomotive builders (American Locomotive, Baldwin, Cooke, and Rogers). The heaviest of these, the H-22 class Baldwins, weighed 184,000 lbs. on drivers and 207,000 lbs. without tender.[135]

The Erie Railroad began the Portage Viaduct truss replacement project construction on May 25, 1903. The Erie determined the original foundations and towers were still in good condition and adequate for the increased dead and live loads of new truss spans and heavier locomotives, but the spans would need replacing.[136] Frank A. Howard, Erie assistant engineer, and Erie bridge engineer Mason R. Strong, under the direction of Erie chief engineer C. W. Bucholz, designed and planned the trusses and installation. The work was completed on December 13, 1903.[137] The 1903 span replacement project allowed the Erie H-20 Consolidations and their H-21 and H-22

[131] Board of Railroad Commissioners, "Buffalo Div.—Bridge No. 16," 1252.
[132] Westing and Staufer, *Erie Power*, 94-95.
[133] Erie Railroad Company, *Sixth Annual Report of the Board of Directors to the Bond and Share Holders, Fiscal Year Ending June 30, 1901,* 20.
[134] Burt, personal communication with the author, January 2019.
[135] Westing and Staufer, *Erie Power*, 94-95.
[136] "New Spans of the Portage Viaduct, Erie R.R.," 120.
[137] "New Spans of the Portage Viaduct, Erie R.R.," 121; "Reconstruction of the Portage Viaduct," 254.

sisters to use the bridge single or double-headed.[138] Later, between 1911 and 1926, the Erie ordered 211, N-class 2-8-2 "Mikado" type engines from four different builders, the heaviest weighing 256,090 lbs. on drivers and 346,050 lbs. without tender.[139] These were not permitted to double-head across the bridge until after the 1944 tower reconditioning project.[140]

One engineering periodical reported in 1905 that the new spans were

> proportioned for a train load of 4,000 lbs. per lin. ft., preceded by two coupled 123½-ton [247,000 lbs.] locomotives with 53-ft wheelbases and 35,000 lbs. on each of four pairs of drivers [140,000 lbs.] on 4½' centers. This [4,000 lb.] train loading is nominally rather light in comparison with that adopted by some other important roads, but it is compensated for by the low unit stresses allowed, which result in the use of [truss member] sectional areas about as heavy as are found in any corresponding structure. The train load is considered to be, in reality, a matter of little consequence, since the longest span on the Erie system is only 223 ft., and is therefore nearly covered by the locomotives. There are bridges and viaducts of total lengths up to more than 2,000 ft., but they are all made up of spans shorter than that above mentioned, so that their severest stresses are caused by the locomotives.[141]

The Erie's Portage Viaduct 1903 replacement truss loading locomotive weights of 140,000 lbs. on drivers may seem like a small figure considering the on-driver weights of their fleets of new Consolidations, and the much heavier locomotives like the Berkshires that followed. However, other important weight—and force—factors included in the truss member design were unaccounted for in the 1905 engineering periodical article. Around the time of the Portage truss replacement project, railroad bridge design practices were evolving toward modern ratings developed by Theodore Cooper based on factors of locomotive weight, driver spacing, and the effect of moving loads on the bridge. Earlier bridge member dimension calculations typically only accounted for the forces of dead load—the weight of the structure itself—and live load—the weight of the vehicle upon it. Around 1900, railroad bridge engineers increasingly proportioned bridge members based on factors that compensated for the moving load. This factor, known as impact, accounted for the effect of the moving, rotating, reciprocating mass of the counter-weighted locomotive drive wheels and running gear pounding on the rails across the span. The specifications used for the 1903 Portage span replacement compensated for impact by reducing the allowable stresses. Stress in an engineering context is the force per cross-sectional area. The allowable stress factor is used to determine the required cross-sectional area for a bridge member for a given load. The lower allowable stresses of the 1903 design required larger cross-sectional area than bridges built to higher allowable stresses. The "low unit stresses" indicated for the

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[138] Erie Railroad Buffalo and Rochester Divisions and Branches, *Time Table No. 27, effective September 28, 1941.*
[139] Westing and Staufer, *Erie Power*, 122–25.
[140] Erie Railroad, "Portage Viaduct Strengthened and Reopened."
[141] "New Spans of the Portage Viaduct, Erie R.R.," 120.

Portage Viaduct 1903 truss members referred to above resulted in members of adequate dimensions and typical for U.S. railroad bridges of the time.[142]

During the early part of the twentieth century, bridge engineering evolved based on research. The practice of lowering stress levels to account for impact was replaced with formulas that included dead load and the live load divided into two factors. The first factor was the static live load—the locomotive weight; the second was the "dynamic load," or impact factor. Because impact did not have to be accounted for in the allowable stress, higher allowable stresses were used to determine the load-carrying ability of the bridge. The larger cross-sectional area of the bridge members of the 1903 design combined with the higher allowable stress permitted higher member forces when determining the load-carrying ability. This process resulted in more efficient use of materials with members proportioned for the highest required performance. Further research determined that the loading percentage relationship between the live load and dynamic (impact) load varied with speed and the impact factor was reduced with decreasing speed. Using this system, truss member loading allowances for a given span length were calculated based on the locomotive wheelbases (driver axle spacing) and bridge speed limit. The greater the wheelbase to spread the load and the lower the speed to reduce the impact, the heavier the locomotives that could cross a truss.[143]

Despite the apparently light Portage Viaduct 1903 replacement truss locomotive axle loading specification, the Erie Railroad clearly designed the 118'- and 110'-long replacement trusses with the panel proportions and member dimensions to accommodate the combined static weight and dynamic forces of the Erie's new Consolidations. Indeed, it accommodated the later, heavier 4-6-2 "Pacific," Mikado, 2-10-2 "Santa Fe," and Berkshire locomotives.[144] Under normal circumstances, speed on the Portage Viaduct bridge was restricted to a relatively low 30-mph limit owing to its sharply curving western approach.[145]

1943–44 Reconditioning

The 1943–44 tower reconditioning project was associated with new heavy steam locomotives purchased in the late 1920s by Erie Railroad president John Bernet. Under Bernet, the Erie addressed motive power issues and retired hundreds of obsolete steam locomotives. The Erie's new flagship steam locomotive for high-speed freight hauling became the 2-8-4 "Berkshire" type. Between 1927 and 1929 the Erie purchased 105 Berkshires from the three major locomotive builders: American Locomotive, Baldwin, and Lima. The Erie's S-1 through S-4 class Berkshires weighed between 443,000 lbs. and 468,800 lbs., with weight on driving wheels between 267,000 lbs. and 286,500 lbs.[146] The heaviest, the S-4, had a tender weighing 378,000 lbs. for a total weight of 423.4 tons.[147] The Erie assigned the Berkshires to main line freight

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142 Swanson, personal communication with author, January 2019.
143 Swanson, personal communication with author, January 2019.
144 Westing and Staufer, *Erie Power*, 124, 155, 171, 306.
145 Burt, personal communication with the author, January 2019.
146 Westing and Staufer, *Erie Power*, 171.
147 Burt, personal communication with the author, January, 2019.

service between Jersey City and Marion, Ohio.[148] Some of these locomotives, as well as the 1911-1926 Mikados, remained in service into the early 1950s alongside their diesel-electric locomotive replacements.

In the late 1930s, General Motors and new consortiums including American Locomotive Company / General Electric (Alco-GE) developed diesel-electric railroad locomotives powered by large diesel engines spinning electrical generators driving traction motors in the wheel trucks. Diesel locomotive "demonstrator" sets roamed the United States, proving the greater power, efficiency, and reliability of the new motive power technology to potential railroad clients. The Erie Railroad hosted a set of General Motors Electro-Motive Division (EMD) diesel units in November 1939 and was impressed with their hauling capacity. Diesel locomotive building was delayed by the onset of World War II. The Erie, one of the first U.S. railroads to invest heavily in new diesel-electric locomotives, ordered a fleet of EMD FT-type 5,400-hp diesel-electric locomotive sets in 1943. The Erie Railroad planned to assign its new EMD diesel locomotives to its hilly Mahoning and Kent divisions between Meadville, Pennsylvania, and Marion, Ohio, where steam-locomotive-hauled freight trains had to stop to be broken into sections, each with its own steam locomotive, in order to climb the heavy grades on those segments. Strategic assignment of the diesels to that bottleneck was intended to save time, fuel, and labor costs, and to allow for hauling of longer trains.[149] The Erie was the first New York–Chicago railroad to completely "dieselize," and all steam power was gone from the railroad by 1954.[150]

Delivery of the new diesels in 1944 made Erie steam locomotives, including the Berkshires, available for use on other important freight routes. The Erie planned to assign its 423-ton "S engines" to the Buffalo Division.[151] Portage Viaduct was not up to that task, and the Erie had placed it under increasingly prohibitive speed and weight restrictions. In 1934, the Erie restricted all locomotives on the bridge to 10 mph and the freight cars to 20 mph.[152] The same restriction applied in 1941. Train slack action and air braking were also prohibited over the bridge.[153] Locomotive weight was an even greater concern. By September 1941, the Erie had prohibited all S-class Berkshire and R-1 and R-2 class Santa Fe locomotives from operating over the viaduct. Erie Mikados, K-class 4-6-2 Pacifics and R-3 Santa Fes were prohibited from double-heading over it. There were no restrictions for H-class Consolidations.[154] These restrictions meant that heavy eastbound trains pulled by double-headed Mikados had to stop at the west end of the bridge, after which the lead locomotive would cut off and run across the bridge alone. Then the remaining locomotive pulled the train over the bridge. The former lead engine either continued

148 Westing and Staufer, *Erie Power*, 166–71.
149 Erie Railroad, "Diesels to Conquer Heavy Erie Grades."
150 Seely, "Erie Railway," 43–44.
151 Erie Railroad, "Diesels to Conquer Heavy Erie Grades" and "Portage Viaduct Strengthened and Reopened."
152 Erie Railroad Company, Buffalo and Rochester Divisions and Branches, *Time Table No. 13, effective September 30, 1934.*
153 Erie Railroad Company, Buffalo and Rochester Divisions and Branches, *Time Table No. 27, Effective September 28, 1941.*
154 Erie Railroad, *Time Table No. 27, Effective September 28, 1941.*

east to Hornell or returned to Buffalo. This operation required extra locomotives and crews and slowed train movements near Portage.[155]

The Erie Railroad wanted to build an entirely new, double-track Portage Viaduct with new approaches and a new, shallower grade profile, but that project was not a priority under wartime steel shortages. The Erie instead chose to strengthen the towers.[156] The tower reconditioning project began on August 9, 1943. The Erie Railroad's Department of Structures forces at the Port Jervis, New York, shops designed and fabricated the tower improvements, under the direction of chief engineer J. W. Smith and supervised by engineer of structures A. M. Knowles. The project was completed on September 10, 1944.[157] Once the towers were strengthened, single Berkshire steam locomotives could use the bridge, and Mikados could cross it double-headed.[158] Double-heading using two Berkshire or two Santa Fe locomotives was prohibited, but double-heading flexibility was improved as those locomotives were permitted to double-head with Erie Pacifics, Mikados, and R-3 Santa Fes.[159] The Erie raised locomotive speeds over the bridge to 20 mph and freight cars to 30 mph. By 1956, after the Erie had replaced all steam power with diesel, locomotive speed over the bridge had been raised to 30 mph.[160]

After the 1944 strengthening project, the Portage Viaduct remained single-track, the only such bottleneck on the Buffalo Division main line. Switches and signals operated from a manned interlocking plant, PB Tower, located at the east end of the bridge, ensured safe train movement between the double-track approaches and the single track over the bridge. The Erie closed PB Tower at some point between July and September 1949, and the line west of the bridge was single-tracked in 1951.[161]

Bridge Specifications

The Erie Railway's sudden need for rapid design and delivery of the new Portage Viaduct ironwork in 1875 came at an important moment in the development of metal railroad bridge design specifications. The nineteenth century, particularly the decades from 1850 to 1880, saw bridge design evolve from art to science, and railroad bridge engineers associated with the Erie Railway and the Portage Viaduct played a part in that evolution. In particular, Erie engineers were early adopters and promulgators of bridge specification systems that strongly influenced the development of the widely-adopted Cooper bridge rating system.

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[155] Burt, personal communication with the author, January 2019.
[156] Knowles, "Strengthens Viaduct," 200, and "Strengthening Old Viaduct," 773.
[157] Erie Railroad Co., Reconditioning Towers, Office of Engineer of Structures, 1945.
[158] Erie Railroad, "Portage Viaduct Strengthened and Reopened." *Erie Railroad Magazine*, 6–7.
[159] Erie Railroad, Buffalo and Rochester Division and Branches, *Time Table No. 31, effective April 28, 1946.*
[160] Erie Railroad Company, Buffalo and Rochester Divisions and Branches *Time Table No. 42, effective October 28, 1956.*
[161] Burt, personal communication with the author, January 2019; Erie Railroad Buffalo and Rochester Divisions and Branches *Time Table No.35*, *Effective April 25, 1948*; Erie Railroad Buffalo and Rochester Divisions and Branches *Time Table No.38*, *Effective September 25, 1949*; Erie Railroad, *1951 Annual Report*, 8.

Col. Stephen H. Long first presented rules for truss bridge building based on controlled member stresses in the United States in 1830. Long's work was based on French engineer Claude L.M.H. Navier's 1826 publication.[162] Long's contributions were soon followed by Squire Whipple's 1847 *Bridge Building* and Herman Haupt's 1851 bridge-building theories.[163] The key bridge design factor at that time was the live load applied to the structure. Early stress calculation methods were crude, and solutions were empirical. After 1860, U.S. bridges were typically designed to carry uniform loads of 1 ton per foot. As railroad steam locomotives increased in weight, engineers designed stronger but heavier bridges. Bridge designers needed more precise information about bridge member strength in order to design more efficient bridges that could carry live loads using the least amount of material (dead load) in their structure.[164] In the late 1860s and 1870s, bridge builders such as the Edge Moor Iron Company, the Phoenix Iron Company, the Keystone Bridge Company, and the Carnegie Steel Company developed testing machines to determine the capacity and strength of bridge iron truss bars and columns. Based on that information, bridge builders could then set more efficient bridge member standards and specifications on a more scientific basis.[165] Even so, bridge members were still specified with additional material thickness to provide an imprecise "factor of safety" buffer. Until about 1874, bridge design was mostly carried out by a handful of bridge companies, each with its own proprietary patented truss design, areas of geographical focus, and special relationships with client railroads (like the many Post trusses built by the Watson Manufacturing Company for the Erie in the 1860s and 1870s). These bridge companies competed for bridge contracts more as promoters of their particular bridge truss types than they did for lowest-cost designs to meet client specifications.[166] The first known set of bridge member specifications published by a U.S. bridge manufacturer was *Specifications for Iron Railway Bridges and Viaducts*, issued in March 1871 by Clarke, Reeves & Company of Phoenixville, Pennsylvania.[167] This set of specifications is considered the "parent of the multitude that have followed."[168]

The second known published set of U.S. railroad bridge specifications was *Specifications for Iron Bridges* prepared by George S. Morison for the Erie Railway in 1873. This was the first set of bridge specifications developed by and for a specific railroad.[169] The Erie bridge specifications were featured in engineering periodicals such as the October 1873 edition of *Van*

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[162] Christianson and Marston, *Covered Bridges,* 58-60, 80-83, and 130-135.
[163] "Historical Sketch of the Development of American Bridge Specifications," *Proceedings of the Sixth Annual Convention of the American Railway Engineering and Maintenance of Way Association, Held at the Auditorium Hotel, Chicago, March 12, 22, and 23, 1905*, vol. 6. (Chicago: Blakely Printing Co., 1905), 199.
[164] Theodore Cooper, "American Railroad Bridges," *Transactions of the American Society of Civil Engineers* 21 (July 1889; reprint, New York: Engineering News Publishing Co., 1889): 21, 34.
[165] Condit, *American Building Art*, 139–40; Dario Gasparini, personal communication with the author, December 2018.
[166] Cooper, "American Railroad Bridges," 22.
[167] James G. Clark, "Specifications for Iron and Steel Railroad Bridges Prior to 1905," unpublished manuscript, 1939, 3–4.
[168] "Historical Sketch of the Development of American Bridge Specifications," 202.
[169] Clark, "Specifications," 12.

Nostrand's Eclectic Engineering Magazine.[170] The Erie needed to replace many of its inadequate old wooden bridges at that time, and Octave Chanute found that the new bridge bid proposals varied so much that he needed a set of standards to guide bridge builders in submitting comparable designs for easier evaluation. Chanute had hired George Morison as Erie Railway Eastern Division resident engineer in 1873 and soon promoted him to system-wide principal assistant engineer. One of Morison's first tasks was to prepare a set of Erie Railway bridge specifications for bidders to follow when designing bridges for the Erie. Morison's specifications included the requirement that bidders submit member strain tables with the plans. Morison's work resulted in "the first printed specification for iron bridges for a particular railroad."[171] Chanute promoted adoption of Consolidation-type steam locomotives on the Erie and directed Morison to formulate the Erie bridge uniform load-bearing specifications according to those locomotive weights. Morison's 1873 Erie specifications closely followed the 1871 Clarke, Reeves & Company specifications, especially the required unit strains and quality of materials, and foreshadowed "some of the ideas afterwards developed by its illustrious author."[172]

In 1873, Chanute also hired Charles C. Schneider to be his chief draftsman and to run the Erie Railway's engineering department in New York City. Schneider (1843–1916) was born in Germany and immigrated to the United States in 1867. His education and experience was in mechanical engineering, and he worked for the Paterson Locomotive works and the Michigan Bridge and Construction Company before working for the Erie. He later worked at the Delaware Bridge Company with noted U.S. bridge engineer Charles Macdonald, and between 1879 and 1883 he worked closely with George Morison on several major Midwest river-crossing projects. He established his own civil engineering practice in New York City in 1883, with the Canadian Pacific Railroad a major client. Schneider was elected president of the American Society of Civil Engineers in 1905. After 1900 he held several positions at J. P. Morgan's American Bridge Works, including vice president and consulting engineer until he died in 1916.[173] While he was at the Erie, Schneider's tasks included checking bridge-building company bid plans, including the strain sheets showing the intended load for each member. This was a relatively new practice, as prior to that time the railroads depended primarily on the bridge companies to determine correct bridge member capabilities and dimensions. Schneider also organized Erie Railway bridge inspection forces.[174]

In 1874, George Morison wrote an unpublished set of internal office bridge specifications for the Erie Railway's in-house use in designing its own bridges.[175] These specifications were drawn up with the assistance of Charles Schneider.[176] According to noted U.S. bridge engineer and

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[170] "Erie Railway Specifications for Iron Bridges," *Van Nostrand's Eclectic Engineering Magazine* 9, no. 58 (October 1873): 372.
[171] "Historical Sketch of the Development of American Bridge Specifications," 203–4.
[172] "Historical Sketch of the Development of American Bridge Specifications," 204.
[173] Frank Griggs, Jr., "Great Achievements: Notable Structural Engineers: Charles Conrad Schneider," *Structure Magazine,* January 2011, 44–55.
[174] "Memoir of Charles Conrad Schneider," *Proceedings of the American Society of Civil Engineers* 43 (January–December 1917): 947.
[175] Clark, "Specifications," 15.
[176] "Historical Sketch of the Development of American Bridge Specifications," 205.

Morison contemporary Theodore Cooper, 1874 marked the start of important changes in the development of railroad bridge engineering. New bridge-building companies were emerging, and bridge engineers, supporting their railroad clients, started to influence bridge design. More railroads developed their own bridge specifications, and some were even designing their own bridges.[177] The 1874 Erie specifications featured "many improvements over that of the year previous," including increased moving load requirements and heavier weights for shorter spans. The specifications still incorporated factors of safety.[178] Reportedly, "in 1874 the bridges which were needed during that year by the Erie were designed by Mr. Schneider, under the direction of Mr. Morison, and the work let on a pound basis."[179] Previously, competitive bridge contracts were typically awarded on a lump-sum basis. Charles Schneider preferred a pound-price basis and prepared the new 1874 bridge specifications accordingly.[180] The *Engineering Record* stated in 1917 that "it is probable that Mr. Schneider was largely responsible for the pound-price method of letting contracts, now so largely superseding the lump sum basis."[181]

In 1875, bridge engineer L. G. F. Bouscaren published his bridge specifications for the Cincinnati Southern Railroad bridges over the Ohio River and Kentucky River.[182] According to Theodore Cooper, these bridge specifications were the "first work of magnitude that was offered for competition upon specifications drawn by an engineer acting exclusively in the interest of [a] Railroad Company."[183] Bouscaren's specifications were significant as the first to use specific steam locomotive wheel diagrams to indicate live load concentrations at wheel-rail contact points, instead of the pounds-per-foot uniform load method then common.[184]

In 1878 and 1879, the Erie, then the New York, Lake Erie & Western Railroad Company, published two related sets of bridge specifications of which Theodore Cooper was coauthor and author, respectively.[185] These specifications were partly influenced by Cooper's time spent and knowledge gained consulting for the Erie with Octave Chanute. The Erie's 1879 *General Specifications for Iron Bridges* was the collective result of Cooper's experience with railroad bridge fabrication, construction, materials testing, and study of defects, and his time as superintendent of the Delaware and the Keystone bridge companies, "supplemented by six months of critical study of the bridges of the Erie Railway as special expert under Mr. Chanute."[186] Cooper's specifications still applied uniform live loads, but also added factors for specific concentrated locomotive driver wheel loads, in this case two coupled 80-ton

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177 Cooper, "American Railroad Bridges," 23.
178 "Historical Sketch of the Development of American Bridge Specifications," 204–5.
179 "Historical Sketch of the Development of American Bridge Specifications," 206.
180 "Memoir of Charles Conrad Schneider," 947–48.
181 "C. C. Schneider, Eminent Bridge Engineer, Dead," *Engineering Record* 73, no. 3 (January 15, 1916): 95.
182 Thomas D. Lovett, *Report on the Progress of Work, Cost of Construction, Etc., of the Cincinnati Southern Railway, November 1st, 1875* (Cincinnati: Wrightson & Co., 1875), 36–38.
183 Cooper, "American Railroad Bridges," 23.
184 Condit, *American Building Art*, 140.
185 Clark, "Specifications," 38.
186 "Historical Sketch of the Development of American Bridge Specifications," 213.

Consolidation-type steam locomotives.[187] His specifications were more detailed than previous ones and included unit strain formulas for all bridge components, "indicating the maximum allowable working stress in each member of the structure in light of the action it was designed to provide."[188] This resulted in more uniform competitive bids and more efficient bridge designs. Cooper's 1879 specification, "although written especially for the Erie road . . . was so general in its nature and so complete in its details that it was applicable to any road."[189] Cooper published the first edition of his *General Specifications for Iron Railroad Bridges and Viaducts* in 1884. Cooper's systems for accounting for locomotive driving wheel and train weights and forces made it easy to design safe, efficient, cost-effective bridges for ever-increasing loads, and by the early twentieth century his E-class bridge rating loading system had become "the almost universal standard for railway bridge design in America."[190]

The design specifications for the Portage Viaduct appear to follow or closely match the Erie Railway's unpublished 1874 internal office bridge design specifications, "using typical components and detailing for standards of strength then maintained by the Erie."[191] In November 1875, George Morison presented a discussion of the specifications used in the Portage Viaduct:

> The trusses of the superstructure are built to the standard of strength in general use on the Erie Railway; they are proportioned to carry a moving load of 3,000 pounds per running foot, with an excessive load of 5,000 pounds per foot, the latter being used in proportioning the floor system between panel points and the variable element in the web system, with maximum tensile strain of 10,000 pounds per square inch. The towers are built to carry a moving load of 5,400 pounds per running foot, in addition to the estimated weight of a double track superstructure; they are also calculated to resist a wind pressure, at right angles to the bridge, of 30 pounds per square foot, exerted on the entire surface of the structure and of a train of cars on top, and one of 50 pounds per square foot exerted on the surface of the structure alone. The maximum compressive strain per square inch allowed in the columns is 6,600 pounds, and the maximum tensile strain allowed in the diagonals, 15,000 pounds; as however the diagonals have an important stiffening function to perform, independent of the resistance to wind effects, it was thought best to use no rods of a less diameter than 1¼ inches, which size is used everywhere, except in the upper section of the towers which sustain the long spans, the batter of the posts making the strains on all the diagonals comparatively uniform.[192]

Significance of the Portage Design

The Portage Viaduct was not particularly structurally innovative. However, it occupies an important place in the development of the large American railway viaduct, and it set a general

[187] Clark, "Specifications," 41.
[188] Condit, *American Building Art*, 139–40.
[189] "Historical Sketch of the Development of American Bridge Specifications," 213.
[190] Petroski, *Engineers of Dreams*, 95–96.
[191] Fraser, "Nebraska City Bridge," 26.
[192] Morison, "New Portage Bridge," 3.

precedent for subsequent examples of the type. Planning cost-effective, level railroad routes through the kind of rolling topography and broad, steep-walled valleys of the eastern United States that characterized the Erie's territory inevitably included the occasional high-level bridge crossing. Whereas European examples were built in stone, American counterparts were mostly built of wood, and later, iron and steel.[193] In 1901, Chicago & North Western resident engineer W. C. Armstrong characterized metal viaducts as "that form of bridge construction [which] evolved in accordance with a minimum of limiting conditions. It is usually employed in building structures over deep and wide chasms where the question of waterway is only of secondary importance; where the designer can place his piers wherever he wishes, make his spans of any length he desires, and where there are no limits imposed except those of safety and economy."[194] The Erie was a "prominent pioneer" of long, high metal viaducts, particularly ones composed of alternating long and short spans on multiple towers.[195] According to noted late nineteenth-century bridge engineer John E. Greiner, the Portage Viaduct set the standard for these bridges and had the distinction of being "if not the very first, the first of particular note, which had towers of two bents only for the different length of spans."[196] More specifically, it had multiple, separate four-post towers, each consisting of a pair of parallel, transverse, horizontally and longitudinally braced, two-post bents supporting the outer ends of alternating short (tower) and long (free or open) spans.

Greiner, in his "The American Railroad Viaduct, Its Origin and Evolution," quoted an unnamed fellow engineer as having said "it requires a great deal of nerve for anyone to say that he originated a certain type of bridge structure or a specification, when it all came about by someone adding a little to what someone has already done."[197] Iron and steel viaduct designs evolved incrementally from the model of the timber trestle, Silas Seymour's 1852 Portage trestle being "the boldest attempt ever made."[198] The first viaducts with spans resting on individual towers made of iron rather than timber are considered to be Liddel & Gordon's 1857 Crumlin Viaduct in Wales and F. C. Lowthorp's 1857 Jordan Creek Viaduct in Pennsylvania.[199]

The era of the American railway viaduct as expressed by the Portage Viaduct began with the 1868 completion of Smith, Latrobe & Co.'s Bullock Pen Viaduct on the Cincinnati & Louisville Short Line Railroad, the first American metal viaduct with individual bents on separate masonry piers. This bridge was novel for Frederick H. Smith's all wrought-iron tower design consisting of columns connected with combined systems of horizontal struts and diagonal tension rods at multiple points to inhibit flexing. The next evolutionary step was seen in Smith, Latrobe & Co.'s 1869 Running Water Viaduct on the Nashville & Chattanooga Railroad and the Lyon Brook Viaduct on the New York & Oswego Midland Railroad, which included

[193] Seely, "Erie Railway," 76.
[194] Robert W. Jackson, "Chicago & Northwestern Railroad Viaduct," HAER IA-44, Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, 1995, 4.
[195] Seely, "Erie Railway," 76.
[196] Greiner, "American Railroad Viaduct," 357.
[197] Greiner, "American Railroad Viaduct," 349.
[198] Greiner, "American Railroad Viaduct," 350.
[199] Greiner, "American Railroad Viaduct," 351.

> complete iron towers of two bents each with a 30 ft tower span between the bents. In these structures appears for the first time the common tower, composed of two bents of two legs each, braced together in all directions, the legs having a transverse batter only, and the bents being connected at their tops by a free or swinging span. This is the typical braced tower as used in American viaducts . . . which demanded a pier stable in itself at each end of the long span.

The next evolutionary step also took place in 1869, when Thomas C. Clarke designed (unbuilt) approaches to the Blackwell's Island Bridge in New York City consisting of braced iron towers with 30'-long spans connecting the bents, with alternating 60'-long free (open) girder spans between them. Clarke considered himself "the originator of the well-known American Railroad Viaduct," which Greiner considered a fair claim. The first major structure built to this pattern was the Baltimore Bridge Company's 1872 Verrugas Viaduct in Peru.[200]

Immediately after the Portage Viaduct was built, its overall tower and span pattern and configuration plus some of its details were adopted in new larger viaducts. For instance, L. G. F. Bouscaren's 1876 Fishing Creek Viaduct and the 1878 McKee's Branch Viaduct, both on the Cincinnati Southern Railroad, incorporated towers consisting of two bents braced in all directions and post feet with friction plates to allow for thermal expansion and contraction movement. Of the many viaducts then built based on this pattern, the 1882 Kinzua Viaduct by Octave Chanute and Clarke, Reeves & Company was the largest ultimate expression.[201] John Greiner said in 1891: "Since the year 1878, general [iron railway viaduct] designs have been practically uniform, embodying the distinctive features which make such structures the most economical."[202]

George Morison was rather humble about his Portage design after construction in 1875: "The new structure is of the same general character as other iron viaducts recently erected by American engineers, differing from them in size and detail rather than in any principle of construction."[203] To Greiner's claim that Morison's Portage design was "if not the very first, the first of particular note, which had towers of two bents only for the different length of spans," Morison replied: "If, as the writer [Greiner] says, this was the first structure of its class, the credit for any originality in this way does not belong to any one person."[204] Bridge engineer Henry Grattan Tyrrell echoed John Greiner in 1911, noting, "The modern type of railroad trestle reached its present stage of development with the building of the first iron Portage Bridge in 1875 and has not greatly changed since that time."[205]

The basic "Portage pattern" railroad viaduct design continued to evolve, and many U.S. railroads built similar examples for their early twentieth-century "Era of Improvements" line construction

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200 Greiner, "American Railroad Viaduct," 350-353, 358; quote from page 353.
201 Greiner, "American Railroad Viaduct," 356–57.
202 Greiner, "American Railroad Viaduct," 357.
203 Morison, "New Portage Bridge," 2.
204 Quoted in Greiner, "American Railroad Viaduct," 360.
205 Tyrrell, *History of Bridge Engineering*, 381.

and relocation projects. Evolution and variation are apparent in long- and short-span depth and length proportions, tower post longitudinal and transverse member connections, and how spans rested on towers. For span length, common practice was to design these bridges with a long-to-short span ratio of 2:1, the same ratio (100' to 50') that George Morison inherited by default at Portage. The 2:1 span length ratio required much deeper long spans, which sometimes presented connection design issues where deeper and shallower deck girders met at the top of the same column. Some bridge engineers found that the long-short span ratios could be adjusted to be a little less than 2:1 to arrive at the most economical proportions for a given bridge, for instance on the Chicago & North Western (C&NW) Railroad's 1901 Boone Viaduct (HAER IA-44), which has long and short span lengths of 75' and 45' respectively.[206] C&NW engineers E. C. Carter and W. H. Finley, as well as consulting engineer George Morison, who is thought to have had considerable design influence, designed the Boone Viaduct.[207] The long-to-short span ratio adjustment often meant that a uniform deck girder depth could be adopted across the structure—7' in the case of the Boone Viaduct. This feature had significant incidental positive aesthetic impact, resulting in a much more streamlined longitudinal elevation profile that created the appearance of a continuous thin deck girder ribbon across the tops of the viaduct towers (which in these cases also had a corresponding slightly wider longitudinal profile). The effect can also be seen in other landmark examples of pre–World War I viaducts, like the Indianapolis Southern Railway's 1906 Tulip Viaduct in Green County, Indiana, or the 1908 Northern Pacific Railroad High Bridge at Valley City, North Dakota. On the Erie Railroad, the in-house bridge engineers chose to continue with a 2:1 long-short span ratio with alternating deep open span and shallow tower span girder depths on its pre–World War I Belfast, Fillmore, and Moodna viaducts. These structures all have alternating 80'-long, 9'-deep long spans and 40'-long, 5'-6"-deep short spans.[208]

Viaduct tower post connection types and locations also evolved in the early twentieth century. Diagonal braces continued to be incorporated in longitudinal and transverse tower panels; however, stiffer, built-up structural steel members eventually replaced round-section tension rods with their threaded adjustment turnbuckles. Evolution is also visible in the number and location of retained horizontal struts, which were reduced by degree, depending on the bridge design. In 1876, George Morison commented:

> So far as I know, all iron trestles or viaducts of similar design, erected prior to the new Portage Bridge, have had the feet of the posts in the towers connected by horizontal struts, both longitudinally and transversely. In the Portage bridge, the longitudinal strut is dispensed with [some were added in later strengthening campaigns], [and] the transverse strut is retained. . . . Mr. [Charles] Macdonald has since erected viaducts . . . in which . . . the use of horizontal struts is dispensed with in both directions. I accept this design as an improvement.[209]

[206] Jackson, "Chicago & Northwestern Railroad Viaduct," 6.
[207] Jackson, "Chicago & Northwestern Railroad Viaduct," 11.
[208] Seely, "Erie Railway," 90–91.
[209] Quoted in Macdonald, "On the New Portage Bridge," 238.

The most persistent retention of horizontal struts appears to have been a single line of longitudinal and transverse struts around the bottom of tower posts, forming braces to stiffen towers at their base. This configuration was employed at the abovementioned Boone, High Bridge, and Tulip, and the Erie's Belfast, Fillmore, and Moodna viaducts, and appears as a common feature of many early twentieth-century viaducts. In addition to the bottom row of tower post struts, some viaducts also had upper panel horizontal struts on the transverse sides of the towers only, as seen in the Erie's Belfast, Fillmore, and Moodna viaducts. Some viaduct designs, like High Bridge, retained both longitudinal and transverse struts at every tower panel, like the Portage Viaduct. Other viaducts, such as Boone and Tulip, had no longitudinal or transverse upper panel struts at all. The responsible engineers and the specifics of their decisions regarding strut employment remain to be explored, although reduction of material with retention of safety are understood.

One Portage Viaduct design feature that was perpetuated on the major pre–World War I Erie Railroad "cutoff" viaducts but does not appear to have been adopted in general U.S. railroad viaduct design is the way the spans rest between and within the tops of the viaduct towers. The Portage Viaduct's 1903 replacement spans were placed below the tops of the 1875 tower posts, supported by new transverse plate girder "headers" (cross-caps) in order to support the deeper deck truss and girder ends while maintaining the original 1875 deck height (see large format photo no. HAER NY-54-36). The Erie chose to incorporate that functional but not particularly attractive feature at its all-new Belfast, Fillmore, and Moodna viaducts. This feature does not appear in contemporary railroad viaducts, where the continuous ribbon of same-depth girder spans rests directly on top of the tower posts or on transverse beams (cross-caps) atop the towers, contributing significantly to a more streamlined visual effect.

George S. Morison's Portage Viaduct can indeed be considered a design milestone in the development of "large and lofty" American railroad viaducts, as Morison called them.[210] American industrial landscape photographer David Plowden, in his book *Bridges: The Spans of North America*, stated that the "final step in the development of what has been called the modern American railway viaduct was the new Portage Viaduct…Since the completion of the Portage Viaduct, the design of metal viaducts has changed very little, and it is for this reason that the bridge is often called the exemplar of this characteristically American form."[211] Large metal viaduct design continued to evolve in several key areas that remain to be investigated, but clearly the ongoing quest for economy led to even lighter and loftier-looking viaducts.

[210] Morison, "New Portage Bridge," 6.
[211] Plowden, *Bridges*, 74.

PART II. STRUCTURAL/DESIGN INFORMATION

A. General Statement:

1. Character:

The Portage Viaduct was an early, long-lasting example of what its designer George S. Morison called a "large and lofty" long, multiple-span iron bridge.[212] It was a major example of its type for its time, and it occupies a notable place in the evolution of American bridges of the type as a precedent. The Portage Viaduct was remarkable for its longevity, remaining in active, daily, heavy freight rail service for 142 years (1875–2017). Most post–Civil War U.S. wrought-iron bridges were entirely replaced just before or after 1900 with steel structures of similar overall design to the Portage Viaduct. George Morison designed Portage Viaduct with the eventuality in mind of widening the deck for double-tracking and raising the deck height. The original truss spacing accommodated replacement of the original truss spans in 1903, and the towers were strong enough to be retained and further strengthened in 1943–44. Morison's foresight allowed the Portage Viaduct to remain an intact, active, dramatic, and superlative expression of nineteenth-century U.S. bridge engineering to the end of its service life in 2017 when it was replaced by the Genesee Arch Bridge (See figures 33, and 34, and 35).

2. Condition of Fabric:

The Norfolk Southern Railway acquired its "Southern Tier Line" between Buffalo and Suffern, New York—which includes the Portage Viaduct—as part of the 1999 split-up of the Consolidated Rail Corporation (Conrail). Subsequent quarterly inspections in the early 2000s showed that in the Portage Viaduct's pin-connected truss spans the pins connecting the eyebars, turnbuckles, and other truss members were worn and stretched, and the large Loomis nuts holding the pins were subject to loosening. The eyebars were worn, showing signs of slack, and the turnbuckles had caused fatigue cracks due to horizontal movement, which accelerated the pin and eyebar hole wear. The welding of steel plates to the back sides of the wrought-iron tower legs in 1943–44 had caused cracks in the tower legs. Numerous rivets had loosened and were replaced with high-strength bolts to ensure safe operation. These and other structural issues limited the maximum allowable weight for four-axle freight cars on the bridge to 273,000 lbs. (standard loaded freight car weight is 286,000 lbs.) and necessitated a speed restriction of 10 mph, creating an operational bottleneck. Norfolk Southern determined that the bridge had reached the end of its service life, and projected traffic and future freight car weights dictated replacement with a new structure.[213] Its replacement, the steel Genesee Arch Bridge designed by Modjeski & Masters and erected by American Bridge Company, was opened on December 11, 2017. The 1875 Portage Viaduct's iron superstructure and stone and concrete substructure were removed in early 2018.

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[212] Morison, "New Portage Bridge," 6.
[213] Swanson, personal communication with the author, May, 2017.

B. Description:

In 2017, prior to the demolition of the structure, the viaduct retained its 1852 predecessor's masonry substructure, its 1875 iron superstructure design and surviving elements, and major steel elements replaced in strengthening projects in 1903 and 1943–44. This description provides a brief summary of those major dimensions, components, materials, and dates (See Figure 36).[214]

Portage Viaduct is a large 1875 iron and steel railroad bridge carrying the former Erie Railroad Buffalo Division, now Norfolk Southern Railway's Southern Tier Line, over the scenic Genesee River Gorge in Letchworth State Park. The overall dimensions of the metal superstructure are 818' long between masonry abutments, 203'-8" high from the base of the tallest tower to the top of the rail, and 69'-8" wide at the base of the tallest tower. The concrete and masonry piers standing in the Genesee River are 31'-6" tall, for a total structure height of 235'-2".

The substructure supports six towers lettered A through F from east to west. These are further divided into bents and correspondingly numbered piers 1 through 12, and east and west abutments. Each abutment consists of an 1875 regularly coursed, quarry-faced ashlar sandstone block masonry bridge seat wall backed up by a modern concrete approach abutment with perpendicular wing walls. The column feet of bents 1 through 5 and 11 and 12 rest on individual square-plan formed concrete piers of varying heights with battered side profiles, ranging in age from 1948 replacements to the early twentieth century. The cores of piers 7, 8, 9, and 10 are the original 1852 regularly coursed, quarry-faced ashlar sandstone block structures with heavy 1875 capstones. The piers are encased in concrete except for the center of pier 7 and the east and north sides of pier 8, where original stone remains exposed and appears to exhibit damage from the 1875 fire. Pier 8 is almost 100' long north-south, almost twice the length of its adjacent pier pairs, because it originally supported a wide, battered timber brace pier near the center of the 1852 timber trestle. Piers 8, 9, and 10 have beveled, inclined upstream cutwater faces, which were reinforced with a thick layer of concrete in 1948. Piers for bents 11 and 12 and the west abutment were relocated 18' west of their 1852 predecessors in 1875 in order to move bent 11 away from the west gorge lip precipice, resulting in span 11's 118' length. The original 1852 masonry survives here in an unused, regularly coursed, quarry-faced, ashlar sandstone block pier immediately east of bent 11 and the Gorge Trail, and a similar wall incorporated in the retaining wall at the west side of Park Road (the main access road into Letchworth State Park). The tops of piers 8, 9, and 10 are connected by a narrow modern steel Warren deck truss catwalk over the river with a galvanized steel grate deck and cable railings.

The 1875 superstructure design incorporates thirteen deck spans supported by six towers, identified as A through F east to west and further broken down into bents 1 through 12. All thirteen spans were replaced as part of 1903 strengthening improvements. Spans 1 through 6, 8, 10, 12, and 13 are identical 50'-long, 6'-deep riveted steel deck girder spans internally braced with transverse frames with X braces, and lateral X-brace rods across the tops of each panel. Spans 7 and 9 are 100'-long Pratt deck trusses with riveted structural steel plate top chords, built-up laced verticals, pin-connected eyebar bottom chords and diagonal braces with tensioning

[214] This October 2017 description preceded demolition and is written in the present tense.

turnbuckles that are pin-connected to the top and bottom chords. Each panel is stiffened by built-up transverse horizontal struts and sets of lateral X-brace rods across the top and bottom. Span 11 is 118' long and of identical construction. The upper surface of the deck structure carries conventional wood railroad ties, single-track welded steel rail, and galvanized steel grate decks with steel angle railings on both sides of the deck.

The six 1875 towers were substantially reconditioned in 1943–44. The towers are 50' wide longitudinally, with a battered transverse profile, and vary in height and transverse width based on their location in the gorge. The tallest ones, D and E, are just under 200' tall, and tower D is 64' wide at the base. The tower columns consist of riveted, built-up structural iron plates with steel stiffening plates welded to and enclosing their back sides in 1944. The tops of the bent columns support transverse riveted steel plate headers (cross-caps) added in 1903 to support the replacement deck girder and truss spans. The majority of the longitudinal and transverse horizontal struts are 1944 replacements and are rectangular-section, riveted, built-up structural steel with lace and lattice sides, with their ends riveted to the inside faces of the columns. The bottom transverse struts are original 1875 iron components and are pin connected to the tower column bases. Each longitudinal and transverse tower panel contains two pairs of diagonal X-brace rods, an original 1875 pair attached to the outside tower faces by horizontal pins in the columns, and a second, 1944 pair located between the outer rods and mounted to horizontal pins in the strut end gusset plates. Each column foot rests in a cast-iron shoe with the date "1875" cast into it. The north tower column feet are bolted to the masonry piers, and the south column feet incorporate slide plates installed in 1944 to allow for transverse expansion and contraction of the structure.

C. Site Information:

The Portage Viaduct was located at Norfolk Southern Railway's Southern Tier Line milepost 361.66. The bridge structure extended northwest 818' from the east abutment at that point and crossed the Genesee River between the town of Portage in Livingston County, New York, and the town of Genesee Falls in Wyoming County, New York. The nearest population center is Portageville, a hamlet within Genesee Falls approximately 1 mile south of the bridge. The location of the former hamlet of Portage, once the site of rail passenger and freight stations, two resort hotels, a small freight yard, and a railroad interlocking tower controlling train access to the viaduct, lies at the east end of the bridge location on Portageville Road within the town of Portage. This area includes the stone foundations of the Cascade House, a nineteenth-century hotel that once stood southeast of the bridge. The hamlet of Portageville, after which the Portage Viaduct is sometimes incorrectly named, is located south and upstream of the bridge site.

The Genesee River Gorge at the Portage Viaduct is roughly 800' wide overall from lip to lip at level ground and 500' wide between its steep rock cliffs below. This river crossing location at the head of the gorge marks an elbow in the railroad route, with a relatively flat eastern approach across open farmland through Portage to the Genesee River Gorge, and a steeper grade extending north through Genesee Falls to Castile. The original 1851 west approach track alignment swung north off the bridge in a broad arc, straightening out on an almost due north alignment and climbing 80' before leveling off south of Castile. This original railroad grade is still visible just west of the viaduct site. In late 1881 the Erie Railroad realigned and lengthened the west approach between the bridge and Denton Corners Road into an S-bend with sharper curves and flatter grades, completing the double-tracking of the Buffalo Division.[215] Subsequent railroad land valuation maps show that the Erie later blocked the deep cut in the old alignment with a stone-block dam approximately 3,000' northwest of the bridge, forming a firefighting reservoir connected to the bridge by a pipe.

Portage Viaduct's Span 7 crossed the former route of the Genesee Valley Canal, another nineteenth-century engineering feat. The canal, authorized in 1836 and completed in 1862, connected the Allegheny River near Olean with the Erie Canal at Rochester. The section of the canal that ran under the viaduct was built in 1850. The canal was abandoned in 1878 and sold in 1880 to the Genesee Valley Canal Railroad, which constructed portions of its line to Rochester in the canal right-of-way between 1881 and 1883. The Pennsylvania Railroad purchased the rail line in 1902, and it became the Rochester Division. The railroad was abandoned in 1963, and the track bed is now part of the Genesee Valley Greenway Trail, which also comprises nearby canal ruins, including locks, an aqueduct, and a tunnel.[216]

Portage Viaduct's immediate setting lies within the extreme southwestern end of Letchworth State Park, a 14,345-acre component of the New York State Park system established in 1906 on the ca. 1859 former estate of William Pryor Letchworth. The viaduct was located in a spectacular setting within the park, spanning the south end of the upper canyon of the Genesee River Gorge, a long-standing attraction also popularly known as the "Grand Canyon of the East." The 70'-high, 300'-wide Upper Falls, the first of three high falls in the gorge, lies just downstream of the bridge crossing site; the Upper Falls area and nearby park trails provided dramatic views of the bridge. Span 11 crossed over the park's Gorge Trail, which switchbacks down past rustic stone walls and bridges to the Upper Falls picnic area. Tower F stood over Park Road, which leads from the park's Portageville entrance one-half mile to the south on Route 436/19A to William Pryor Letchworth's "Glen Iris" house. The stone retaining wall at the west edge of Park Road at the bridge site incorporates one of the original stone piers for the 1852 timber railroad trestle. Portage Viaduct was a contributing element within the Letchworth State Park Historic District, which was listed in the National Register of Historic Places in 2005.[217]

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[215] William D. Burt, "The Erie's River Line, Part 1: To Build or Not," *Diamond* 5, no. 1 (1989): 9–10.
[216] Partin, National Register of Historic Places Registration Form, section 8, 26–28.
[217] Partin, National Register of Historic Places Registration Form; New York State Department of Transportation et al., "Draft Environmental Impact Statement for PIN 4935.79.101, Portageville Bridge Project, Town of Portageville, Livingston and Wyoming Counties" (Albany: New York State Department of Transportation, 2012), 4.4.11/6-13; US Department of Transportation, Federal Highway Administration, and New York State Department of Transportation, "Final Environmental Impact Statement / Final Section 4(f) Evaluation for Portageville Bridge Project, P.I.N. 4935.79, Wyoming and Livingston Counties, New York," 2014.

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C. Likely Sources Not Yet Investigated:

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George S. Morison Collection, Smithsonian Institution, Washington, DC

Hornell Railroad Museum, Hornell, NY

Salamanca Rail Museum, Salamanca, NY

Western New York Railway Historical Society, Buffalo, NY

Wyoming County, New York historian's office, Warsaw, NY

PART IV. ILLUSTRATED APPENDIX

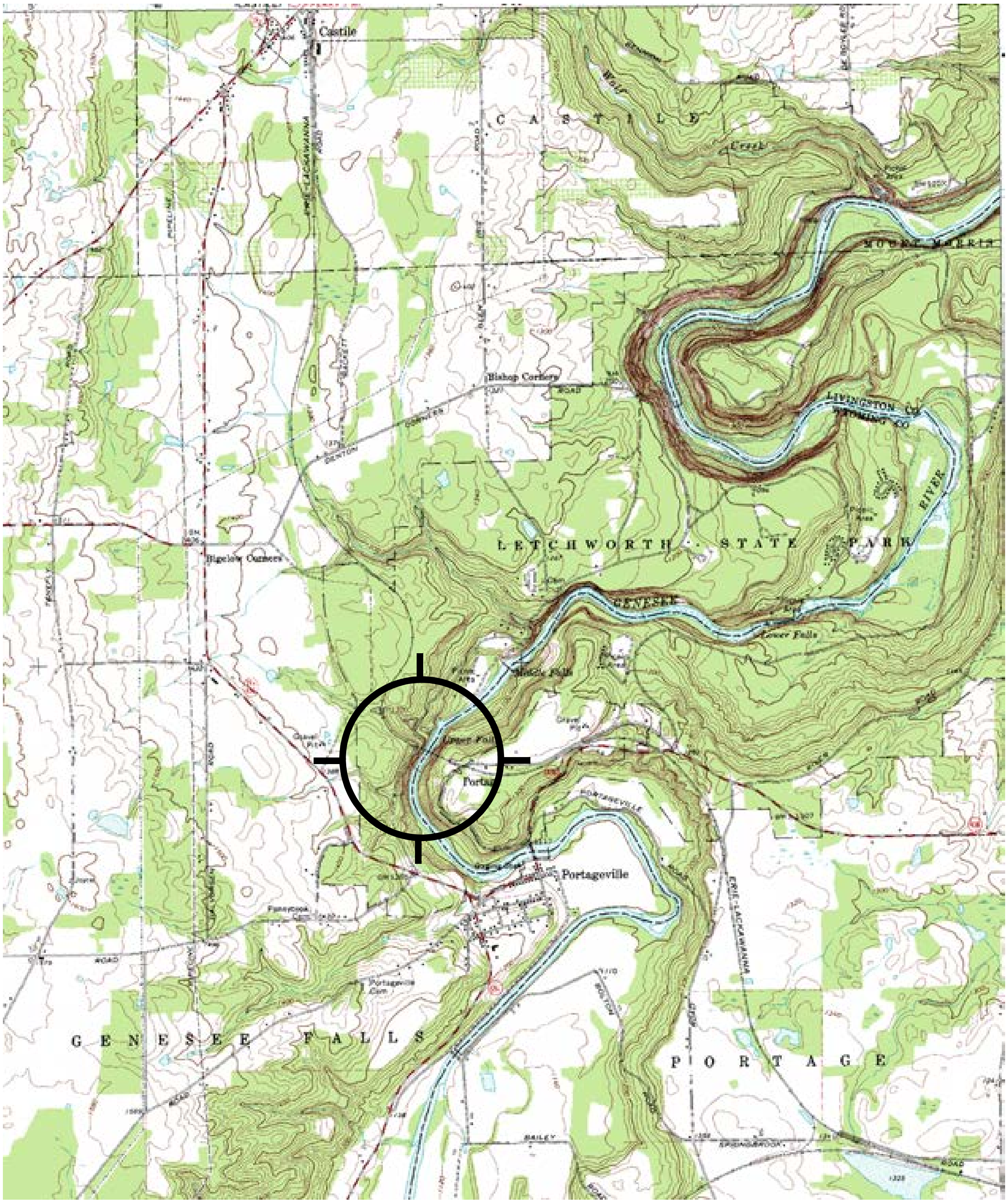


Figure 1. Location of 1875 Portage Viaduct and 1852 trestle over Genesee River Gorge on portion of United States Geological Survey, Portageville, N.Y. 7.5-minute quadrangle map (Scale 1:24,000), 1972.

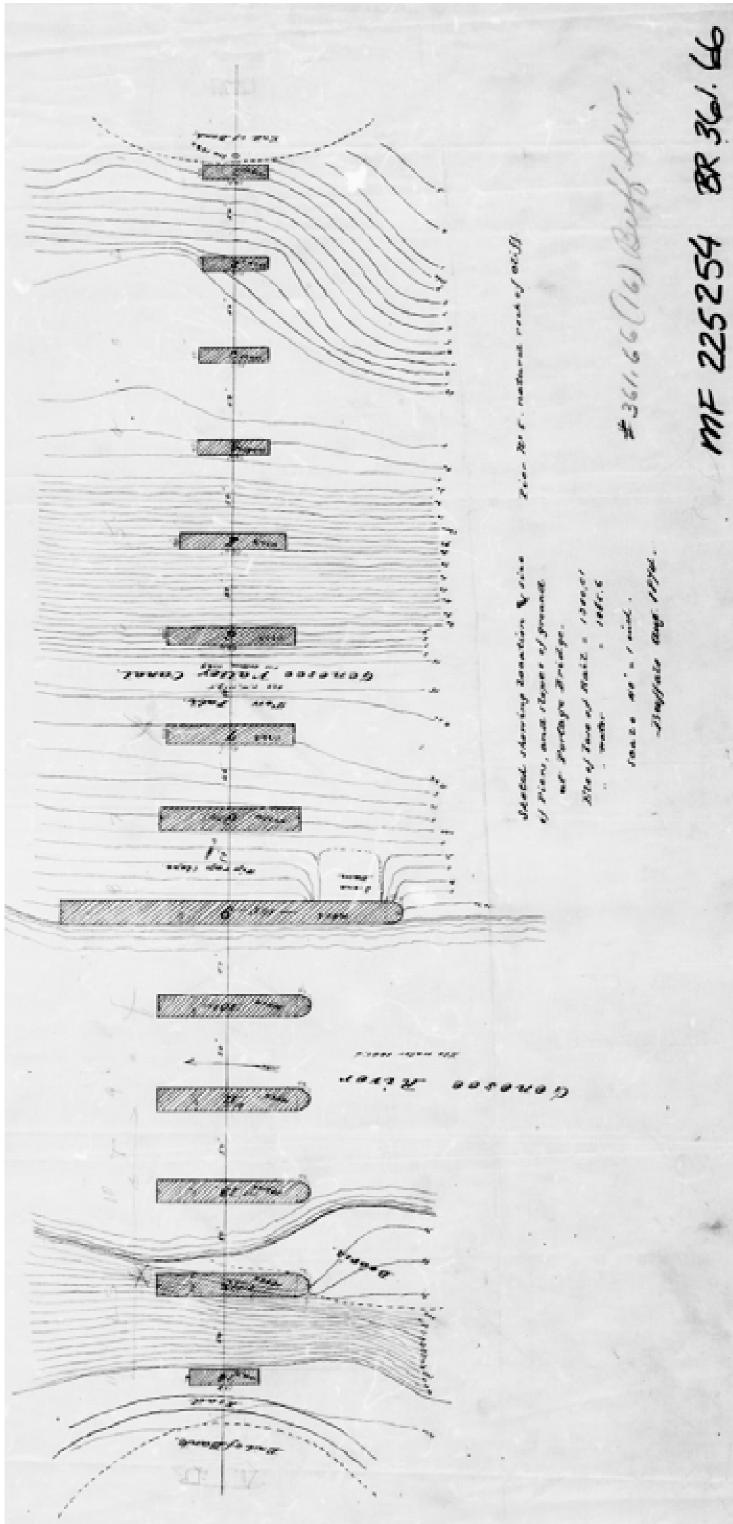
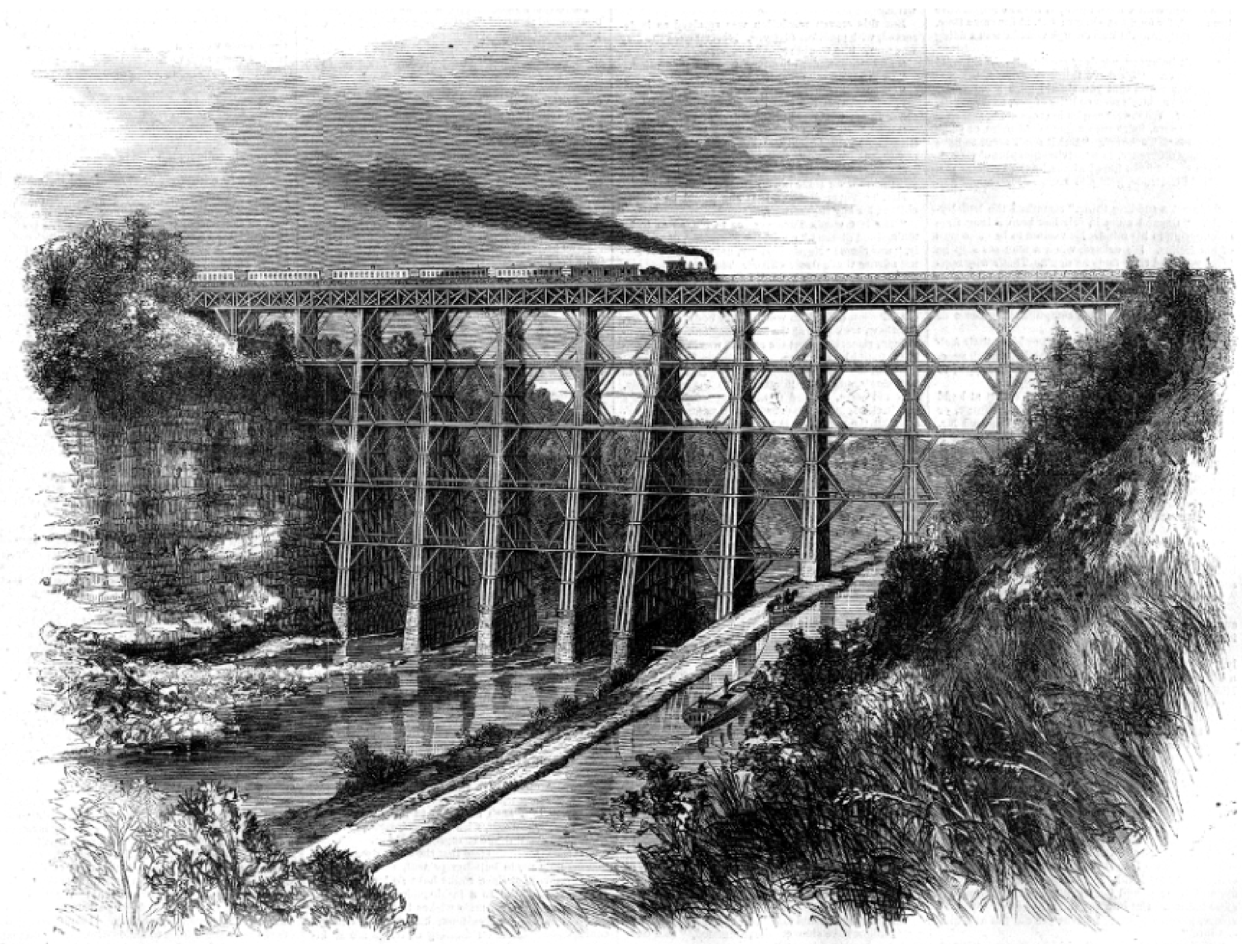


Figure 2. Erie Railway, "Sketch Showing Location and Size of Piers, and Slopes of Ground at Portage Bridge," August 1874. Drawing No. MF 225254/BR 361.66, Norfolk Southern Railway. Note east and west abutments and westernmost pier west of road are omitted in this drawing.



RAILROAD BRIDGE ACROSS THE GENESEE RIVER AT PORTAGE, NEW YORK.—Photographed by Rockwood & Co.—[See Page 718.]

Figure 3. Engraving, "Railroad Bridge Across the Genesee River at Portage, New York," *Harper's Weekly*, November 10, 1866, p.712.

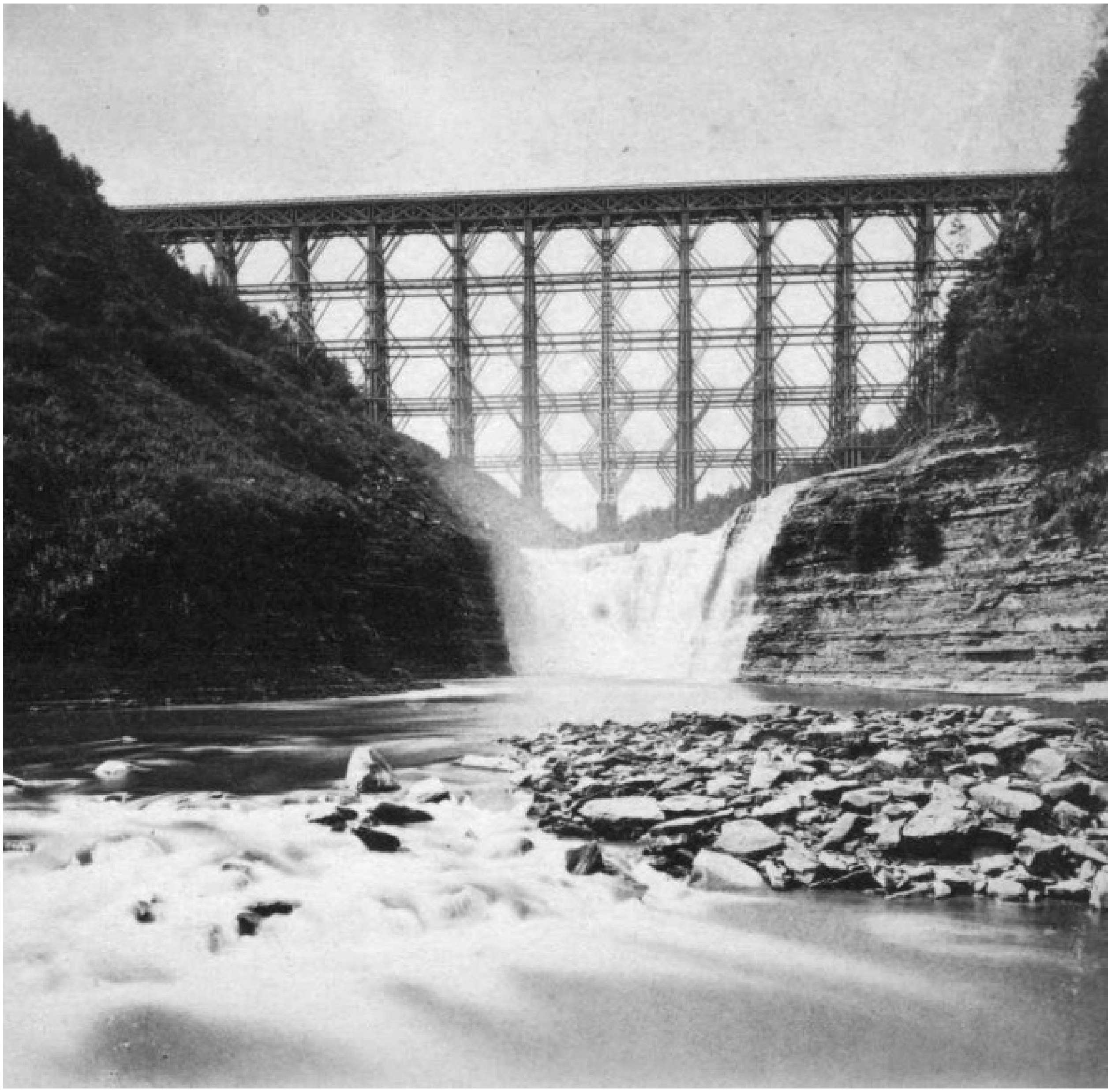


Figure 4. “View of Portage Bridge and Horse Shoe Falls, Scenery at Portage and Vicinity, N.Y., No.6987,” Stereo photograph image by E. & H.T. Anthony & Co., New York, NY. Matt Kierstead collection.

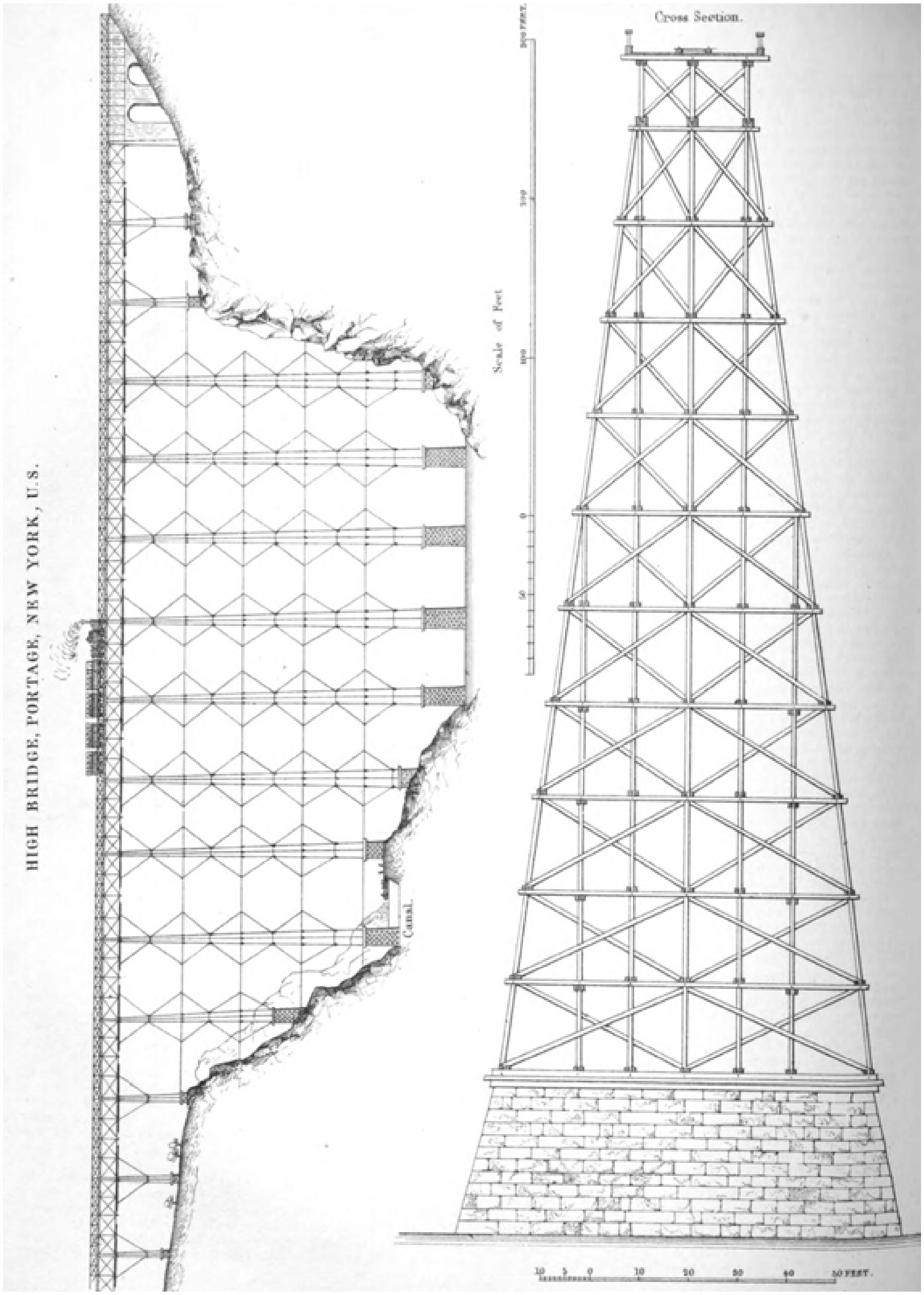


Figure 5. Elevation/section drawing of 1852 Portage Trestle from "'High Bridge, Portage, New York." *Civil Engineer & Architects Journal* 16, no. 227 (February 1853), p.65, Plate 8. Note the masonry arch approach shown is a product of artistic license and was not actually built.

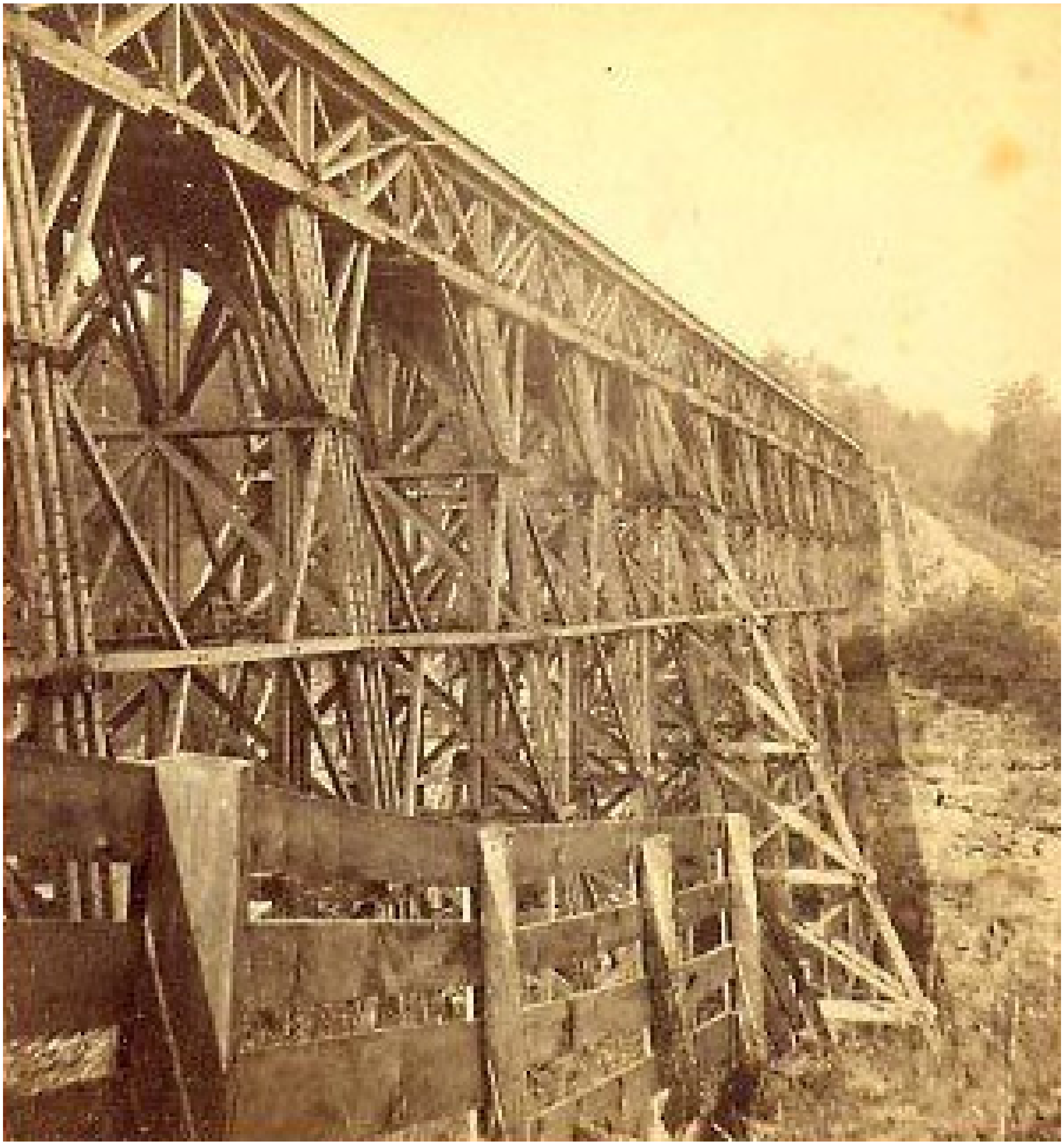


Figure 6. Photo of 1852 timber viaduct showing Long deck truss, view looking west. Source: Norfolk Southern Railway.

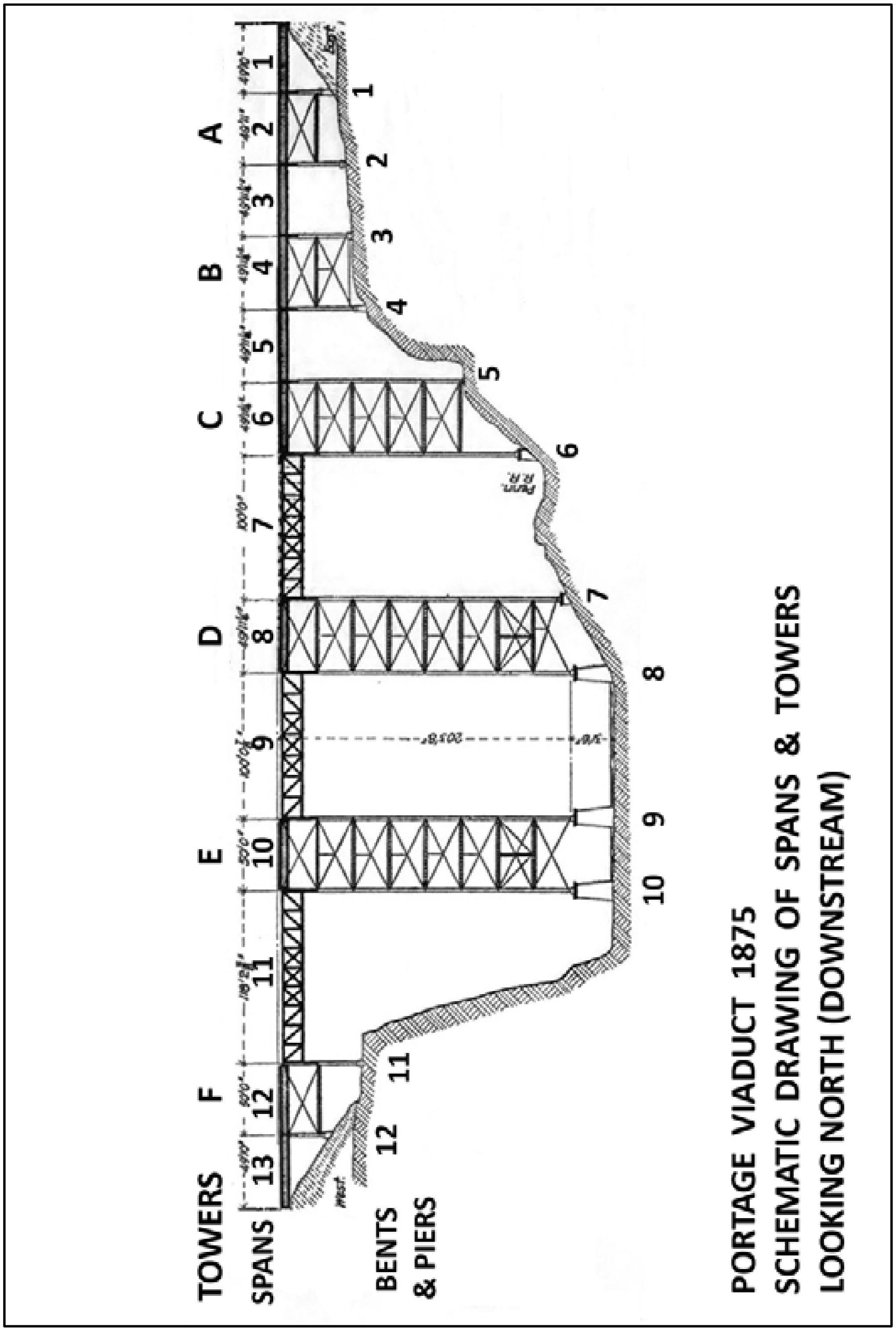
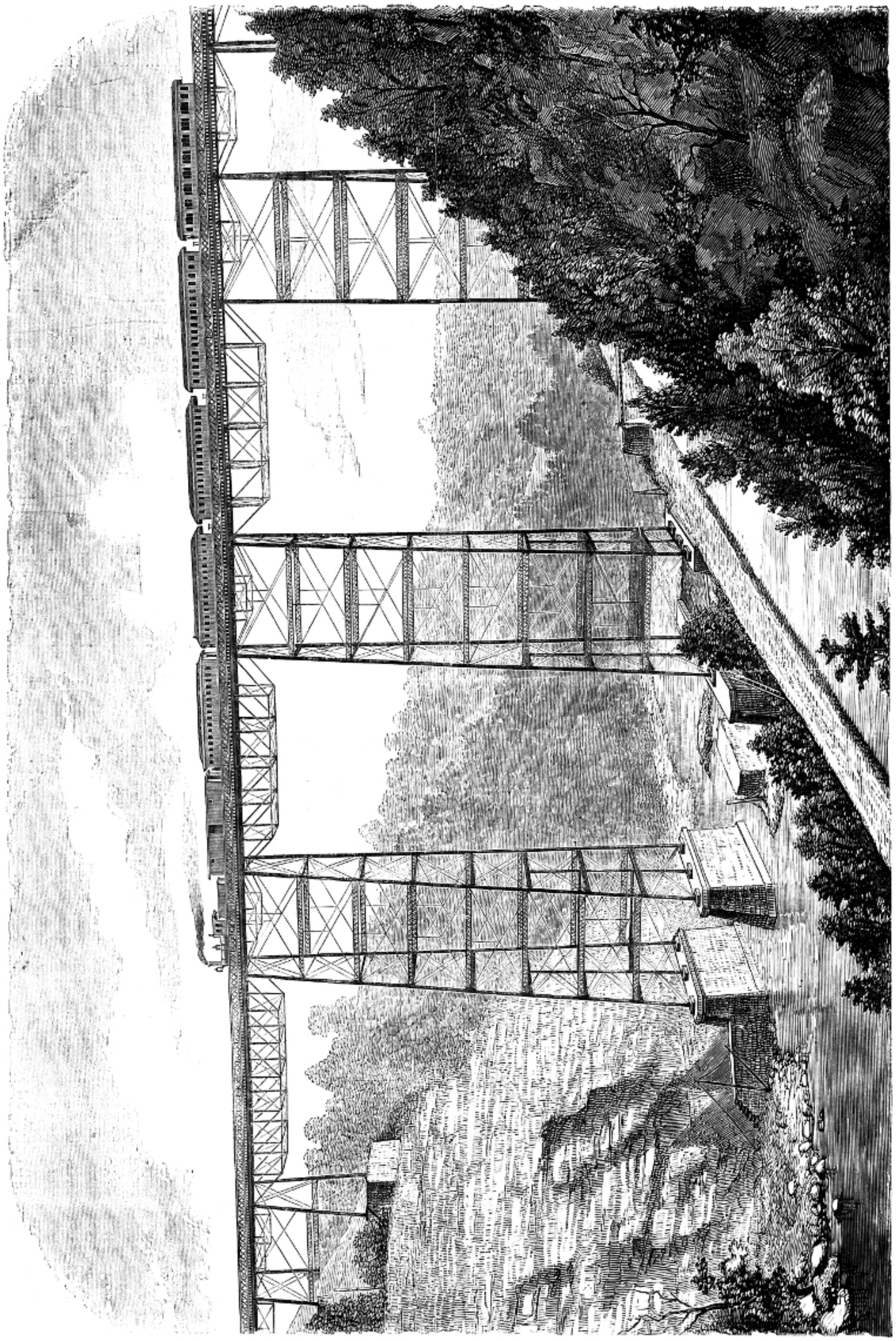


Figure 7. General schematic diagram of Portage Viaduct showing span, tower, pier and bent indications assigned by George S. Morison, based on Henry Grattan Tyrell, *History of Bridge Engineering*, 1911, p. 382.



THE PORTAGE VIADUCT.—NEW-YORK AND ERIE RAILWAY.—DESIGNED BY GEORGE S. MORISON, C.E.—(*See page* 53.)

Figure 8. Engraving, "The Portage Viaduct—New York and Erie Railway—Designed by George S. Morison, C.E.," *Scientific American Supplement*, No.4, January 22, 1876, p. 60.

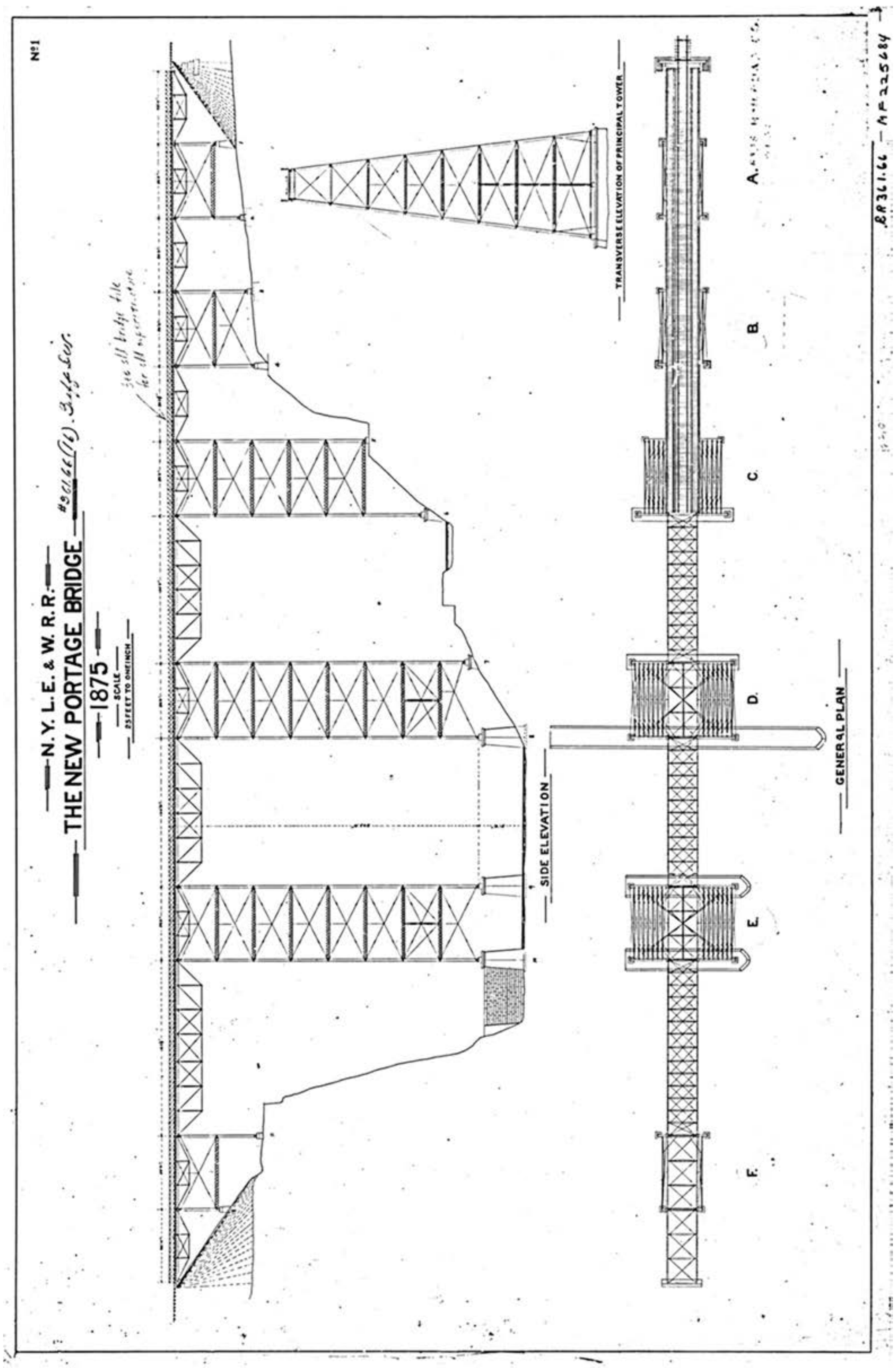


Figure 9. New York, Lake Erie & Western Railroad, "The New Portage Bridge, 1875," Undated (after 1878), Drawing No. MF 225684/BR 361.66, Norfolk Southern Railway. Shows side elevation, general plan and transverse elevation of principal tower.

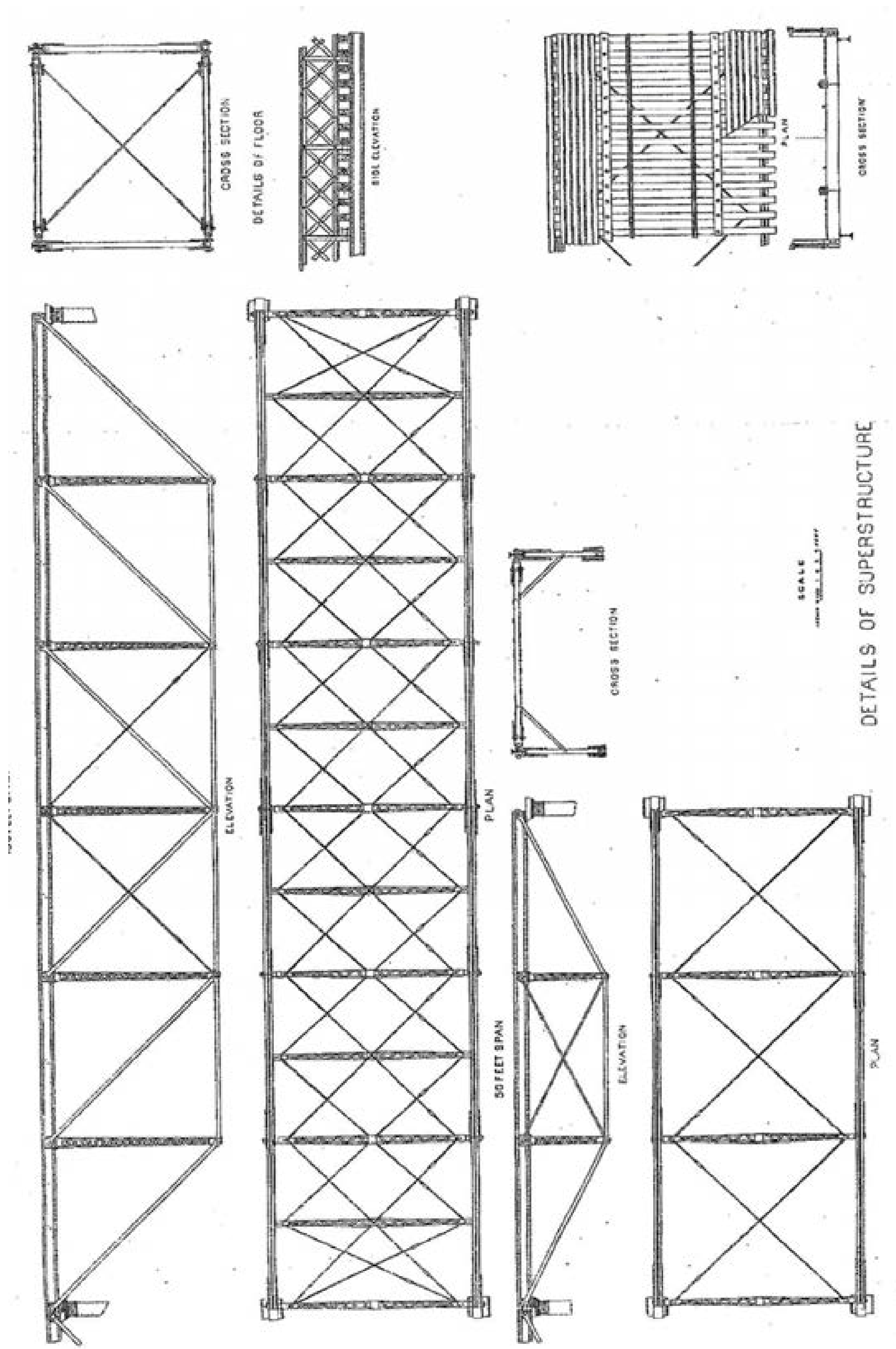


Figure 10. "Details of Superstructure," from George S. Morison's "The New Portage Bridge," *Transactions of the American Society of Civil Engineers* 4 (November 1875), Plate No.3.

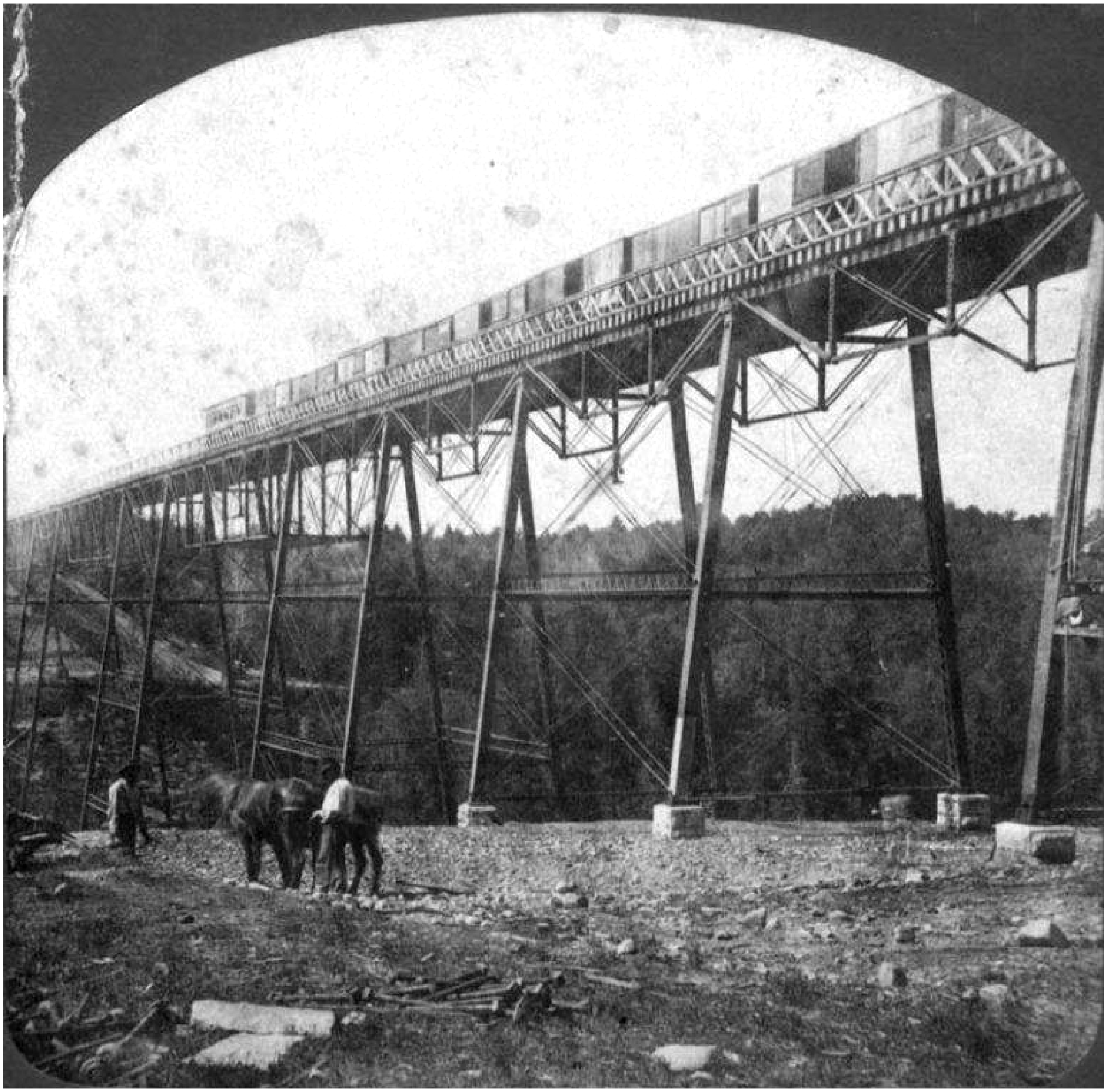


Figure 11. Stereo photograph image of Portage Viaduct looking northwest showing 50' long Pratt deck trusses. Date unknown (ca.1875-1903). Source: Norfolk Southern Railway.

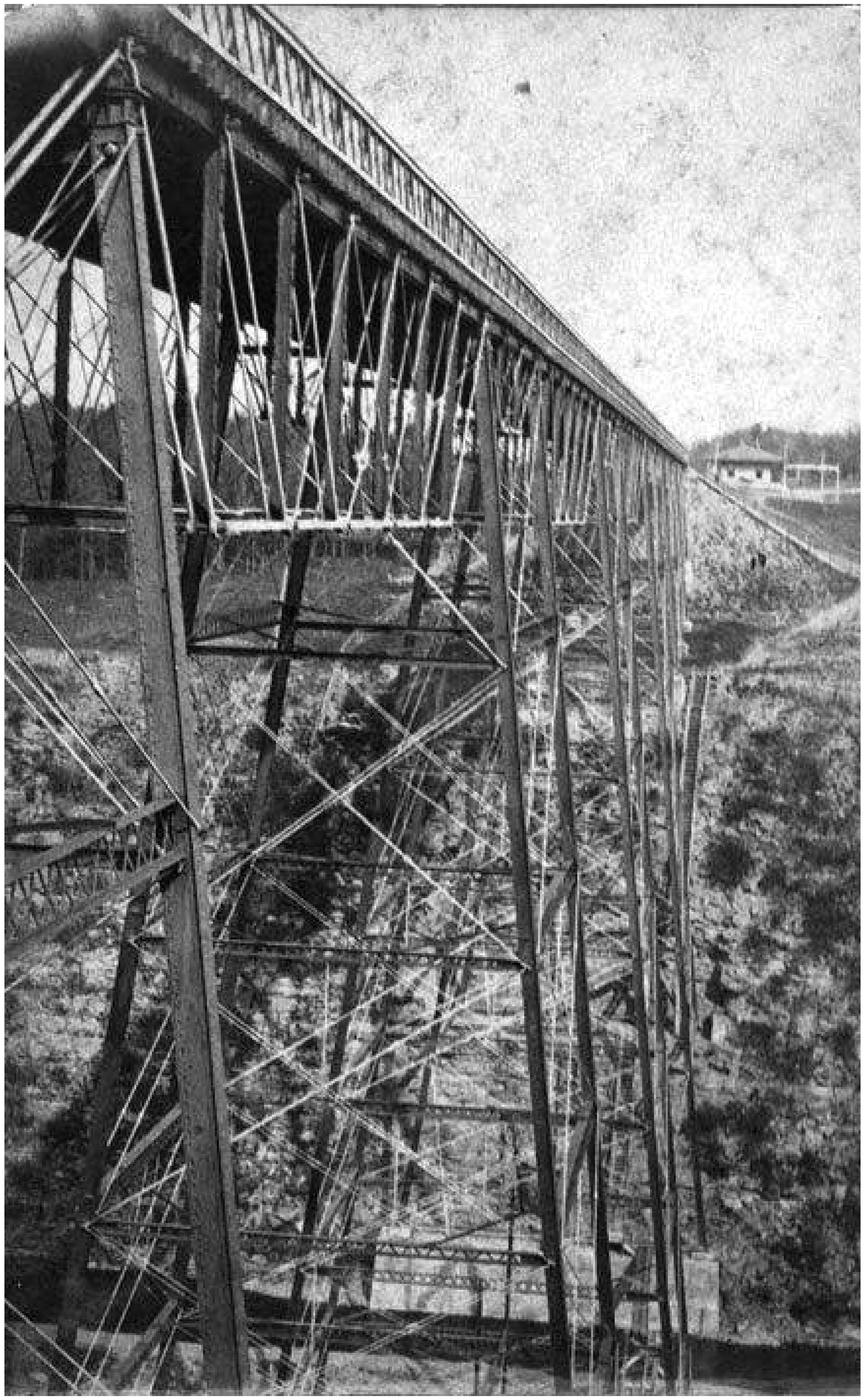


Figure 12. Photograph of Portage Viaduct looking east showing 118' long Span 11 Pratt deck truss. Date unknown (ca.1875-1903). Source: Norfolk Southern Railway.

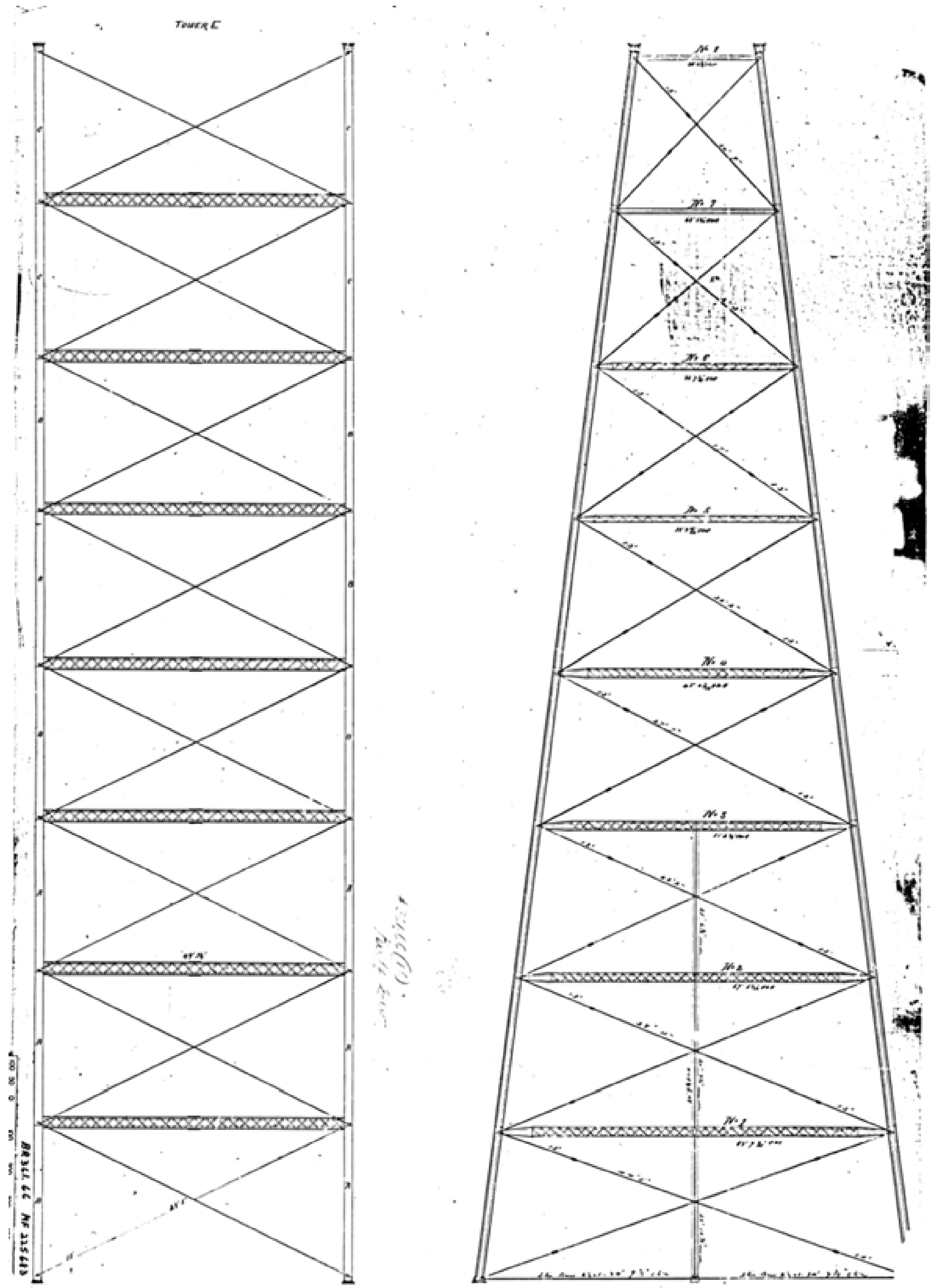


Figure 13. Erie Railway, "Tower E," Undated (ca.1875), Drawing No. MF 225683/BR 361.66, Norfolk Southern Railway. Shows longitudinal and transverse elevations.

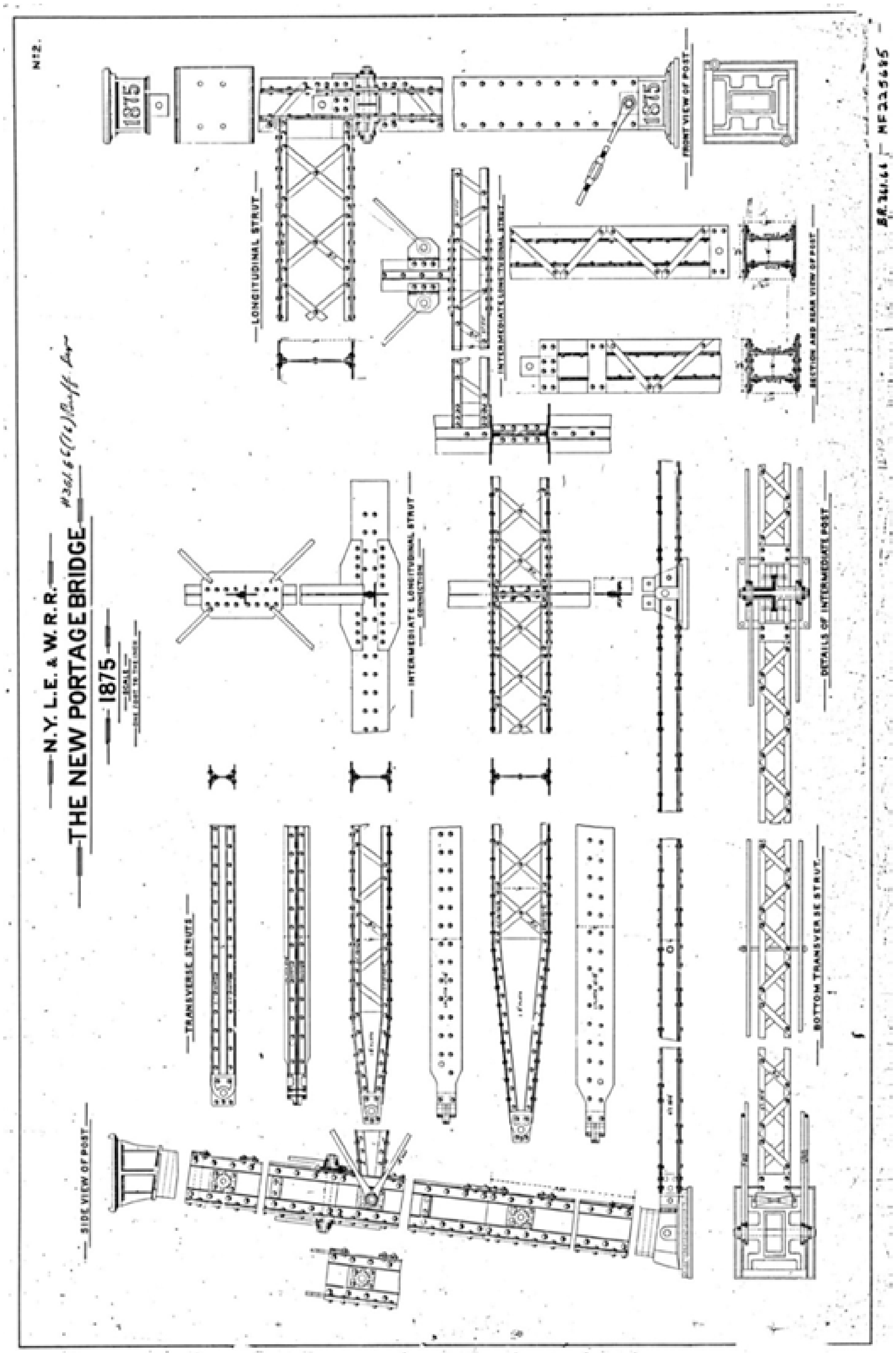


Figure 14. New York, Lake Erie & Western Railroad, "The New Portage Bridge, 1875," [details of struts and posts], Undated (after 1878), Drawing No. MF 225685/BR 361.66, Norfolk Southern Railway.

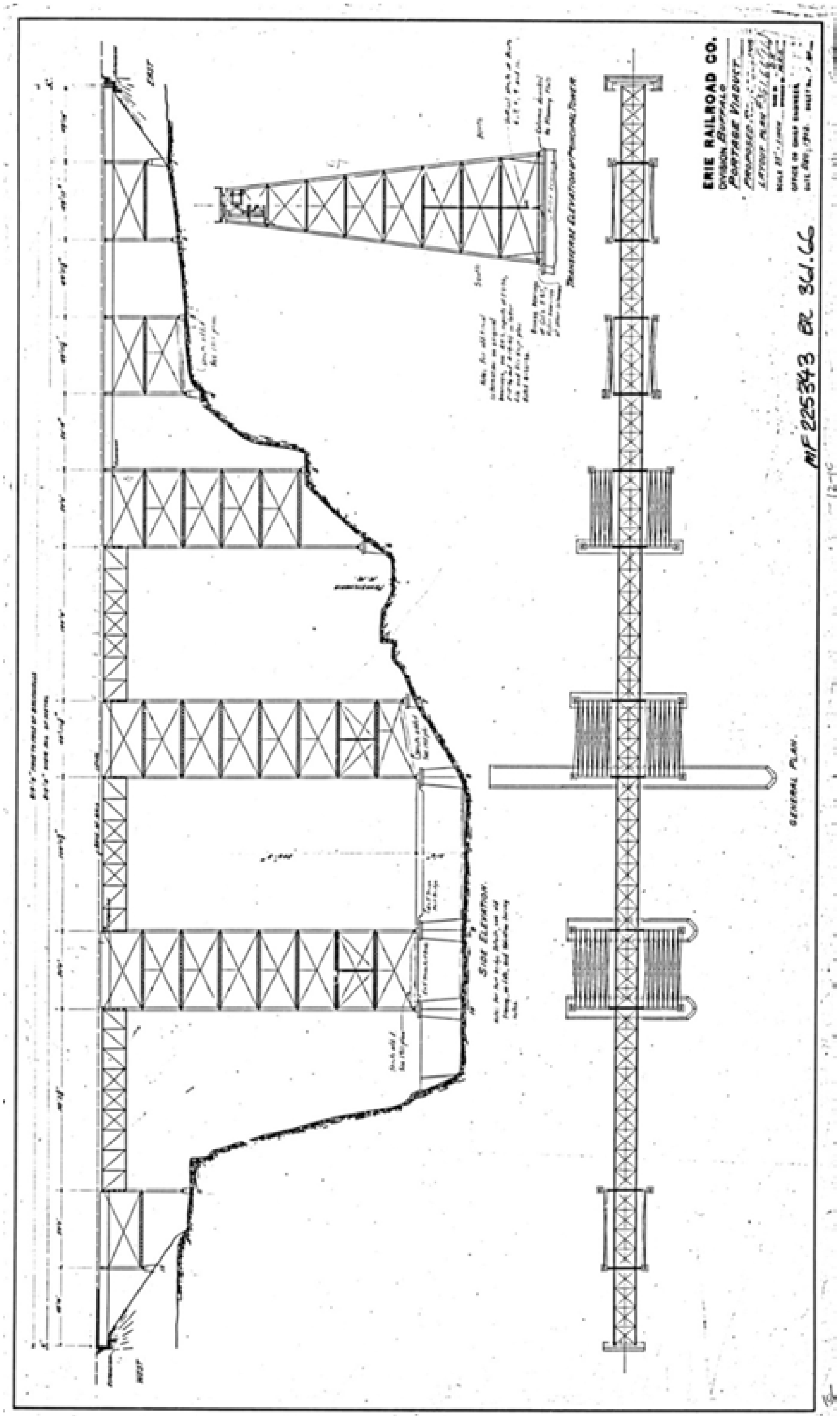


Figure 15. Erie Railroad, "Proposed Remodeling Layout Plan," December 1902, Drawing No. MF 225343/BR 361.66, Norfolk Southern Railway. Note new deck truss and girder spans.

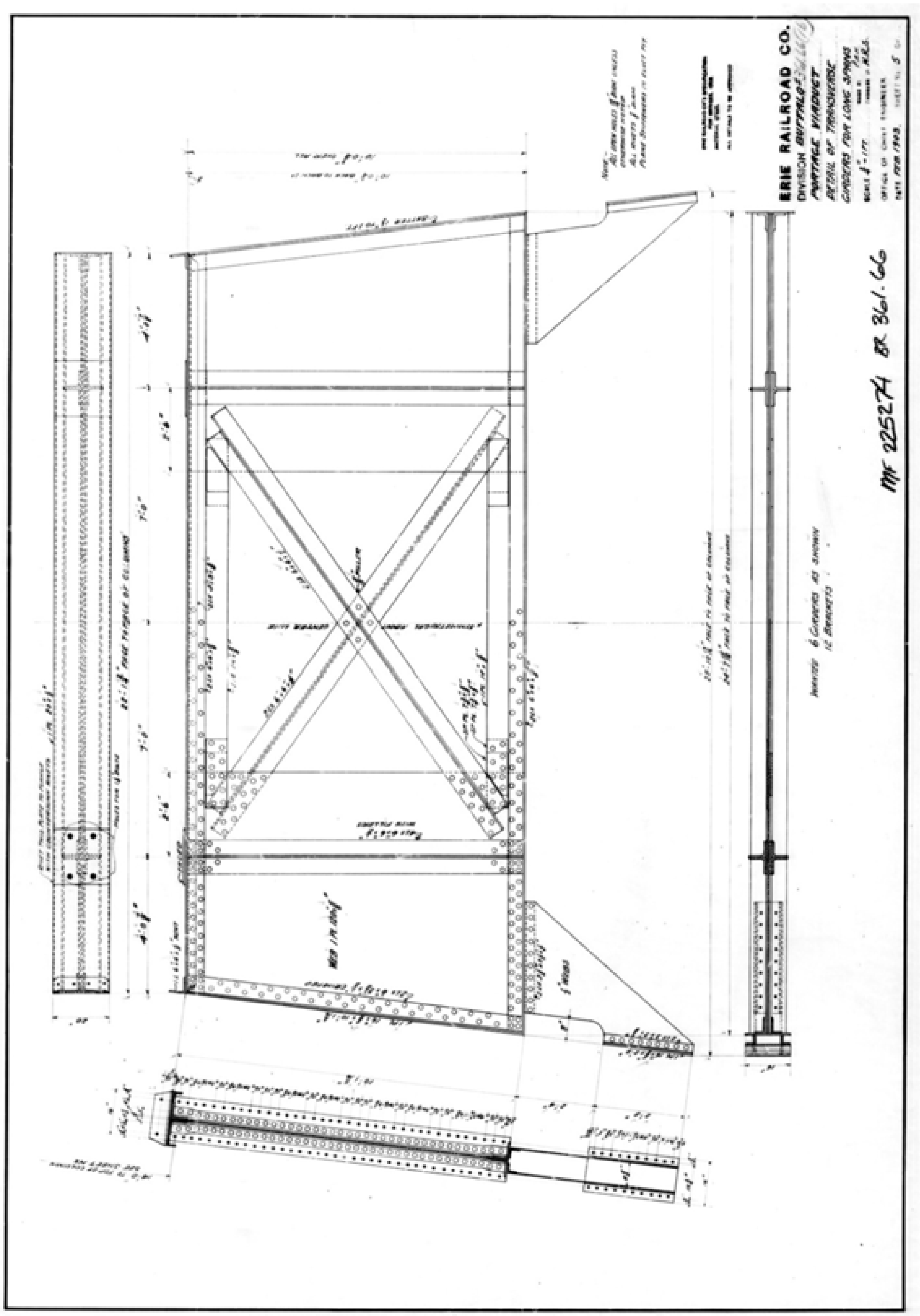


Figure 16. Erie Railroad, “Detail of Transverse Girders for Long Spans,” February 1903, Drawing No. MF 225274/BR 361.66, Norfolk Southern Railway. Girders or “cross-caps” were referred to as “headers” by Erie Railroad.

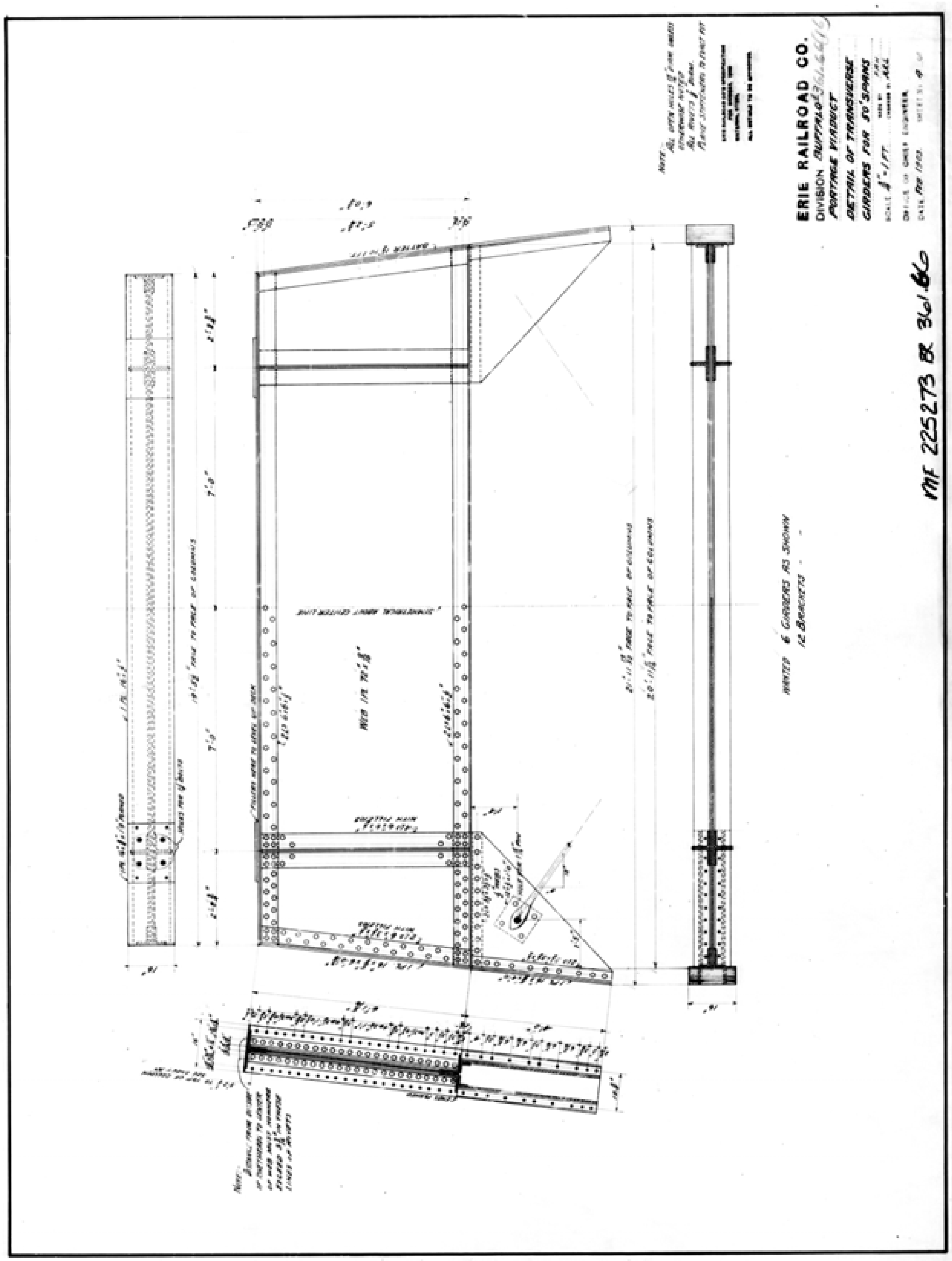


Figure 17. Erie Railroad, "Detail of Transverse Girders for 50' Spans," February 1903, Drawing No. MF 225273/BR 361.66, Norfolk Southern Railway.

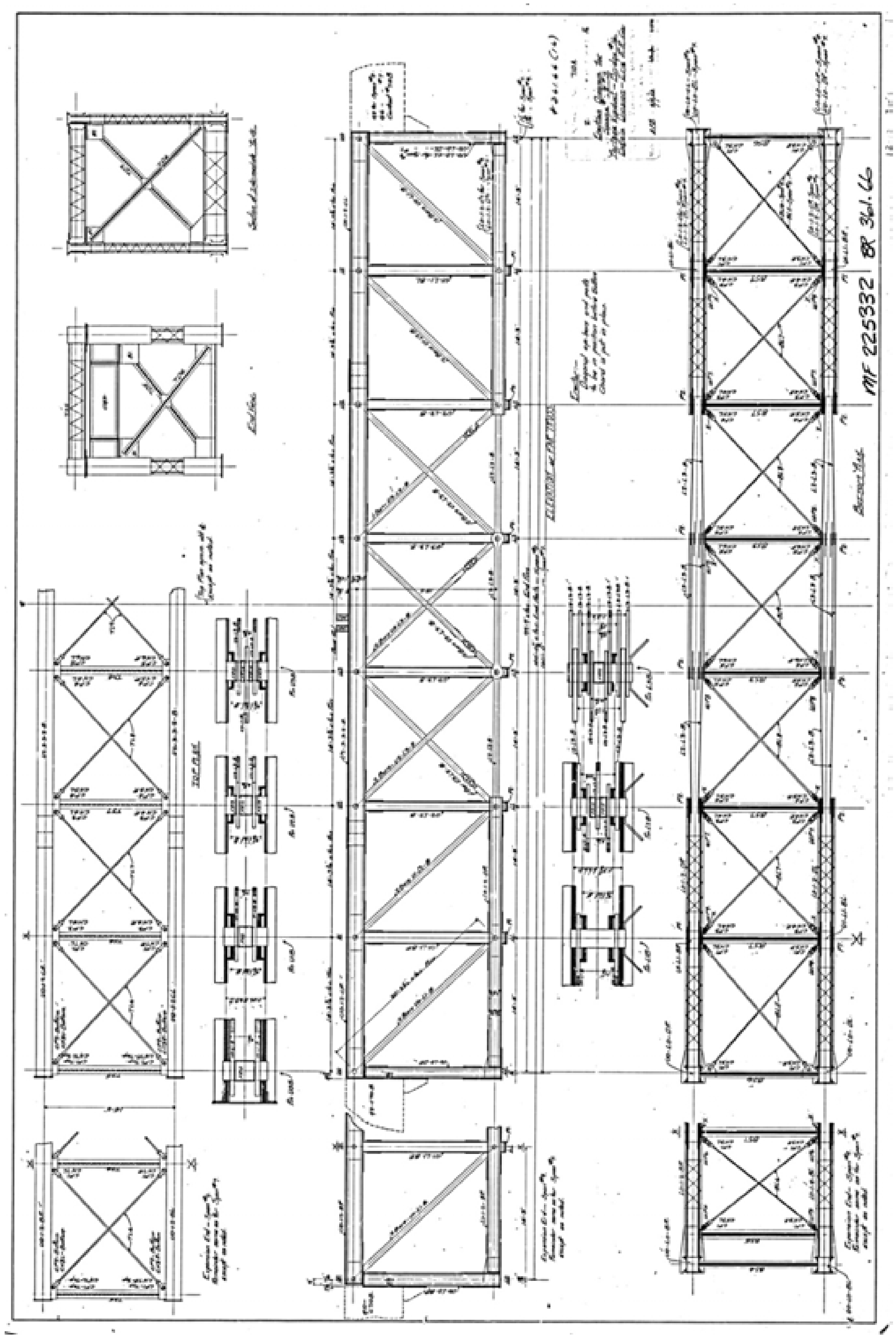


Figure 18. Erie Railroad, "Erection Diagram for Spans 7 & 9," June 4, 1913, Drawing No. MF 225332/BR 361.66, Norfolk Southern Railway.

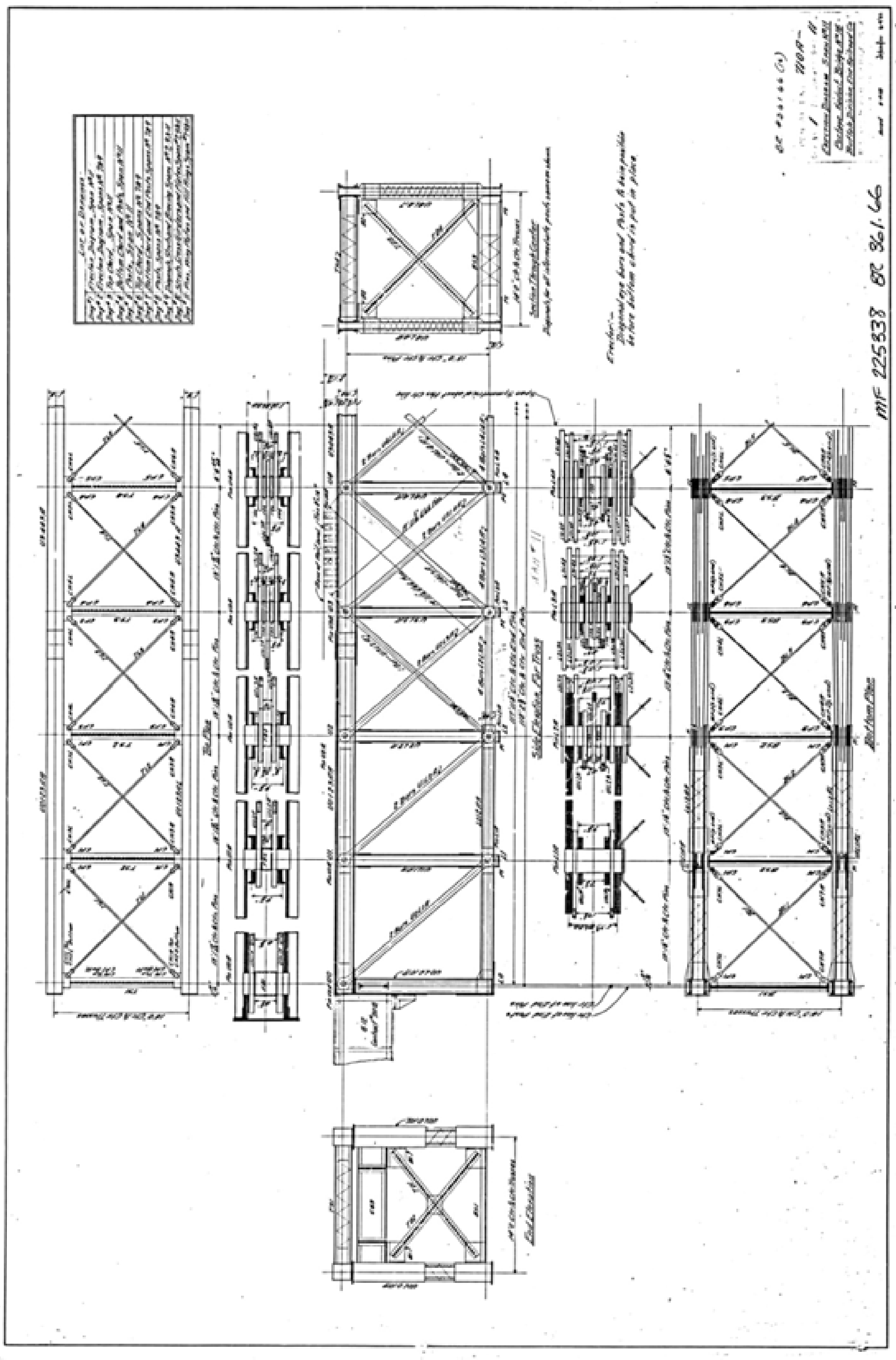


Figure 19. Erie Railroad, "Erection Diagram for Span 11," June 9, 1913, Drawing No. MF 225338/BR 361.66, Norfolk Southern Railway.

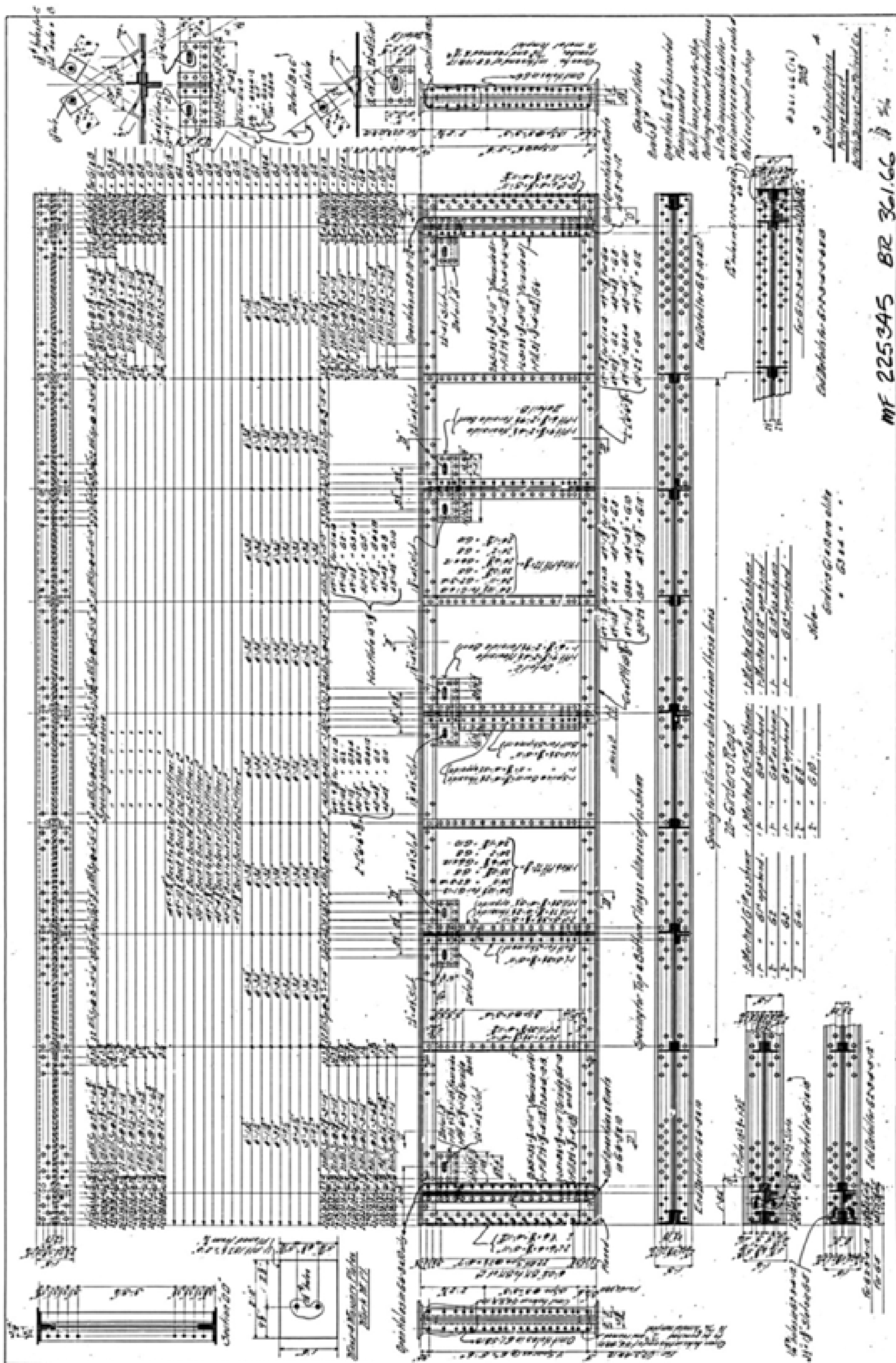


Figure 20. Erie Railroad, "Longitudinal Girders," May 20, 1903, Drawing No. MF 225345/BR 361.66, Norfolk Southern Railway.

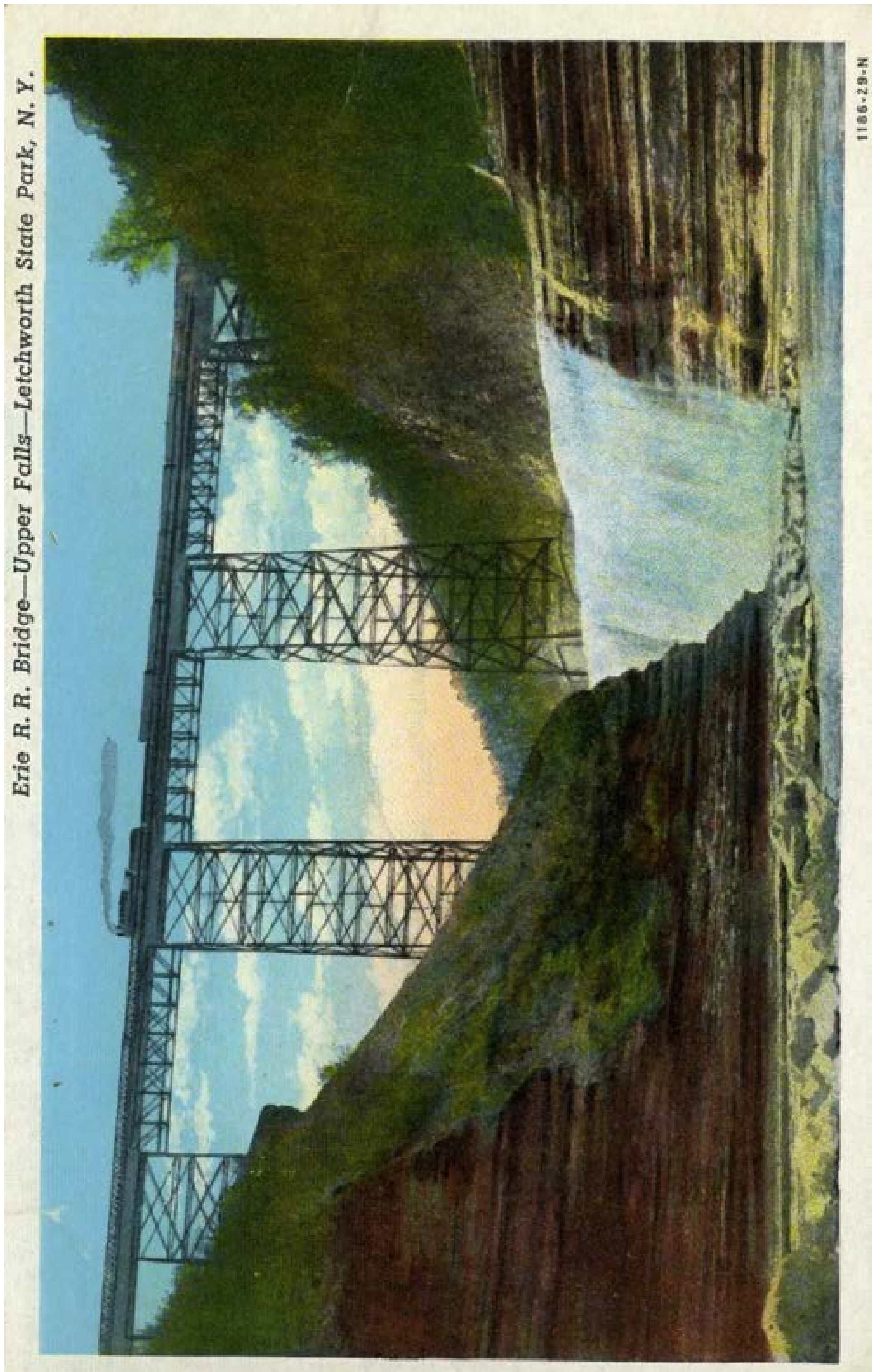


Figure 21. "Erie R.R. Bridge—Upper Falls—Letchworth State Park, N.Y.," hand-colored postcard, Bassett's Art Shop, Perry, N.Y. Genuine Curteich/C.T. American Art, Chicago, IL. Postmarked 1941. Shows 1903 truss and girder spans. Matt Kierstead collection.

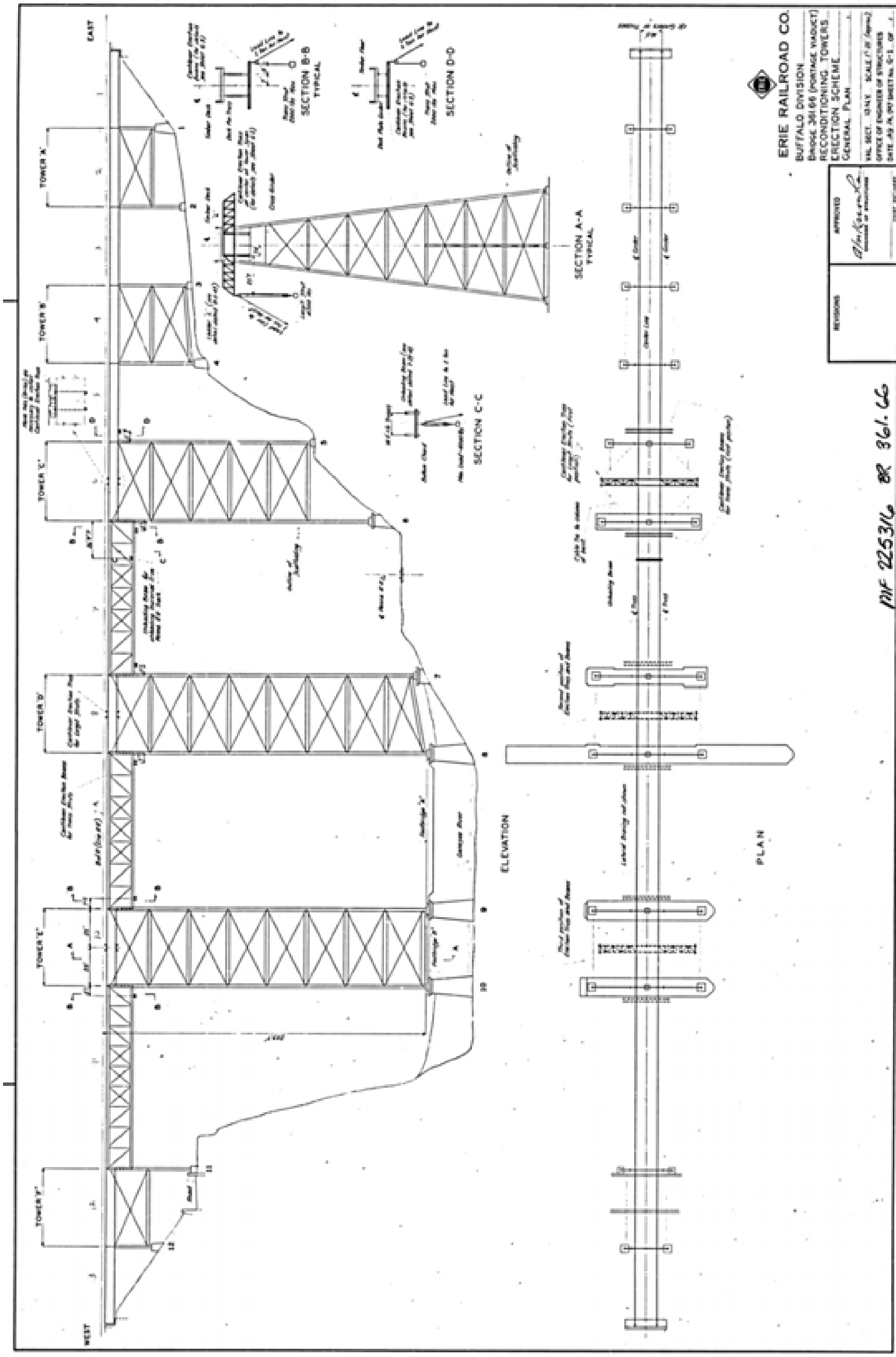


Figure 22. Erie Railroad, "Reconditioning Towers: Erecting Scheme," July 26, 1943, Drawing No. MF 225316/BR 361.66, Norfolk Southern Railway.

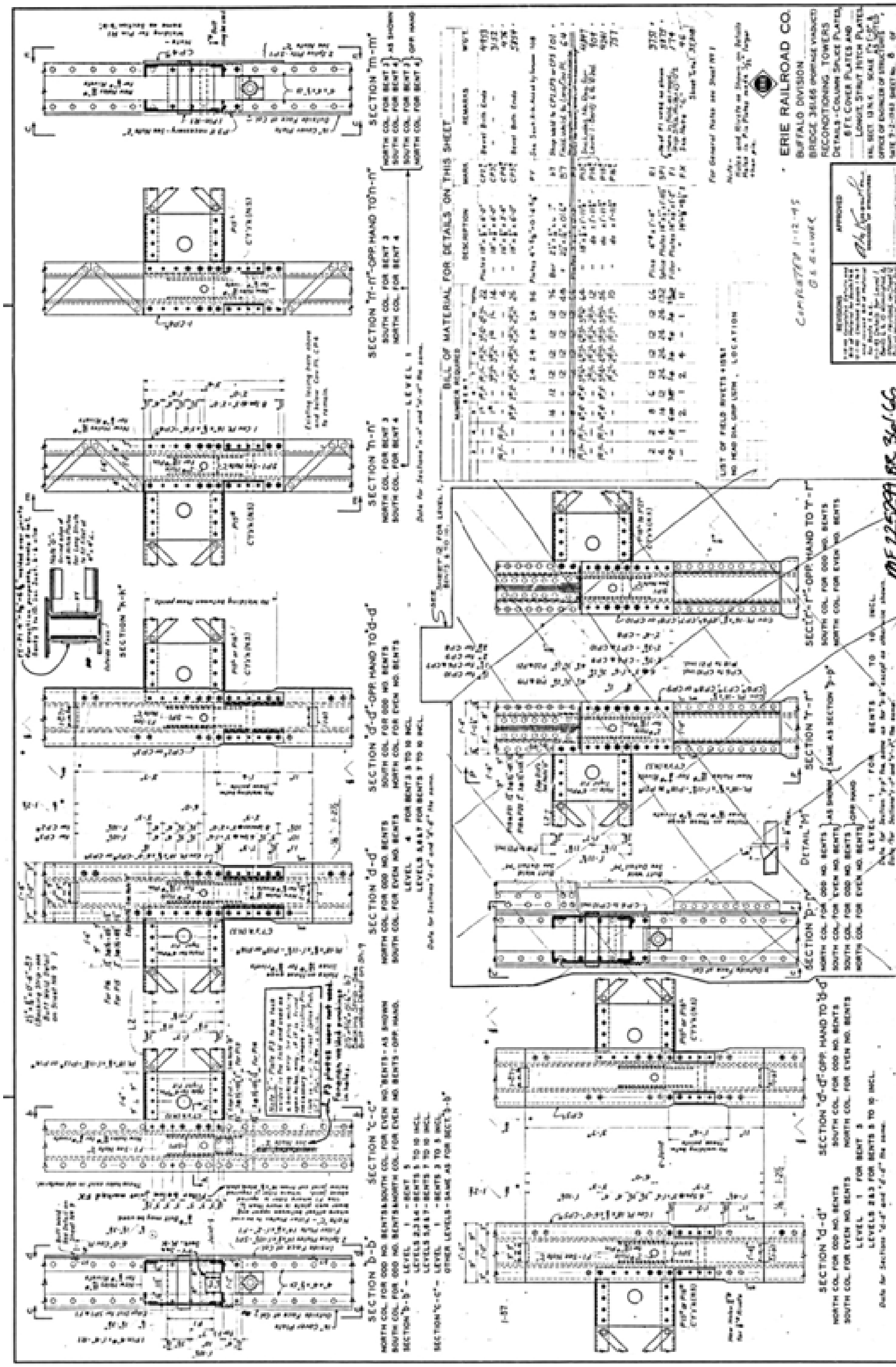


Figure 23. Erie Railroad, "Reconditioning Towers: Details, Column Splice Plates, 6 ft. Cover Plates and Longitudinal Strut Hitch Plates," September 2, 1943, Drawing No. MF 225299/BR 361.66, Norfolk Southern Railway.

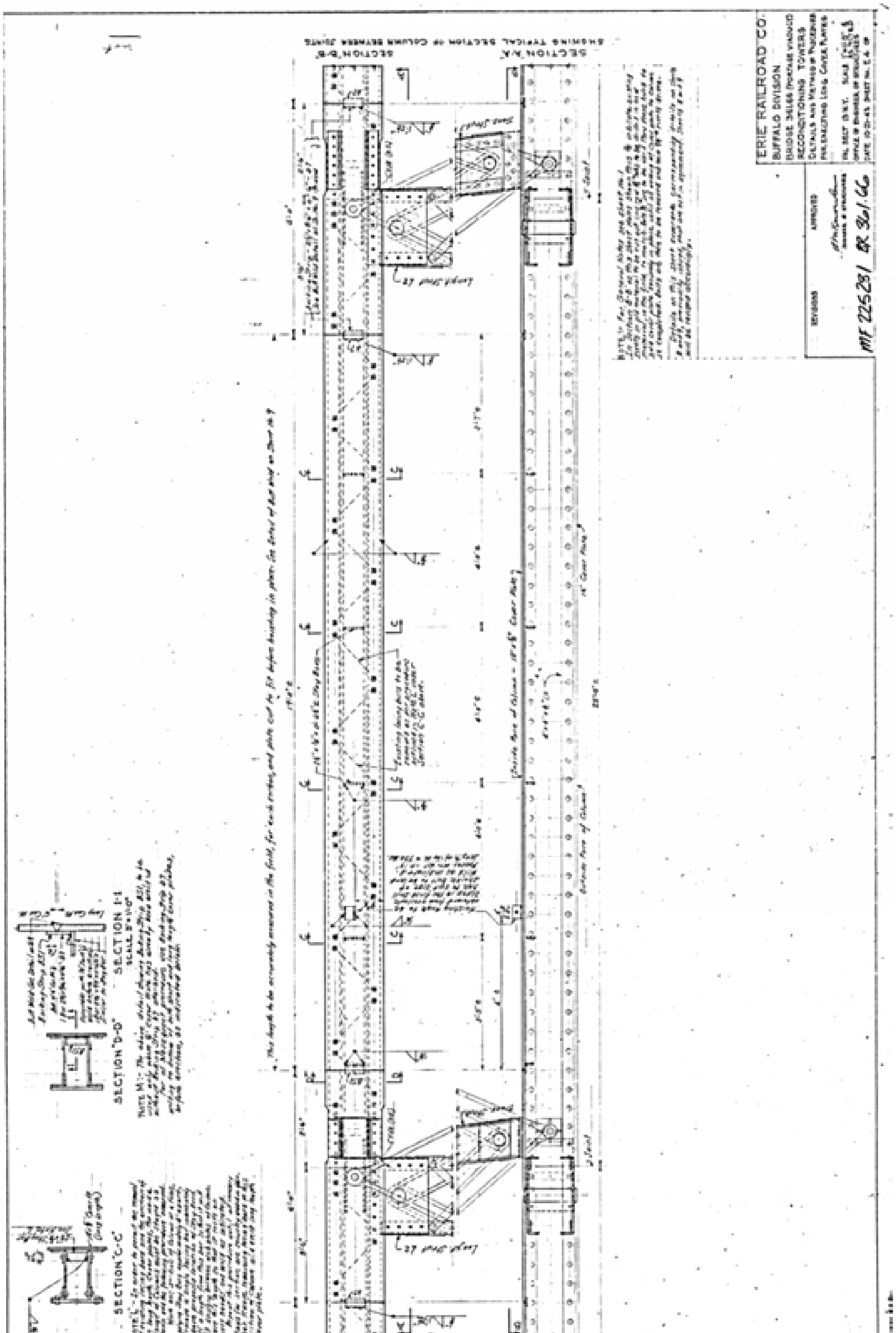


Figure 24. Erie Railroad, "Reconditioning Towers: Details and Method of Procedure for Erecting Long Cover Plates," October 21, 1943, Drawing No. MF 225281/BR 361.66, Norfolk Southern Railway.

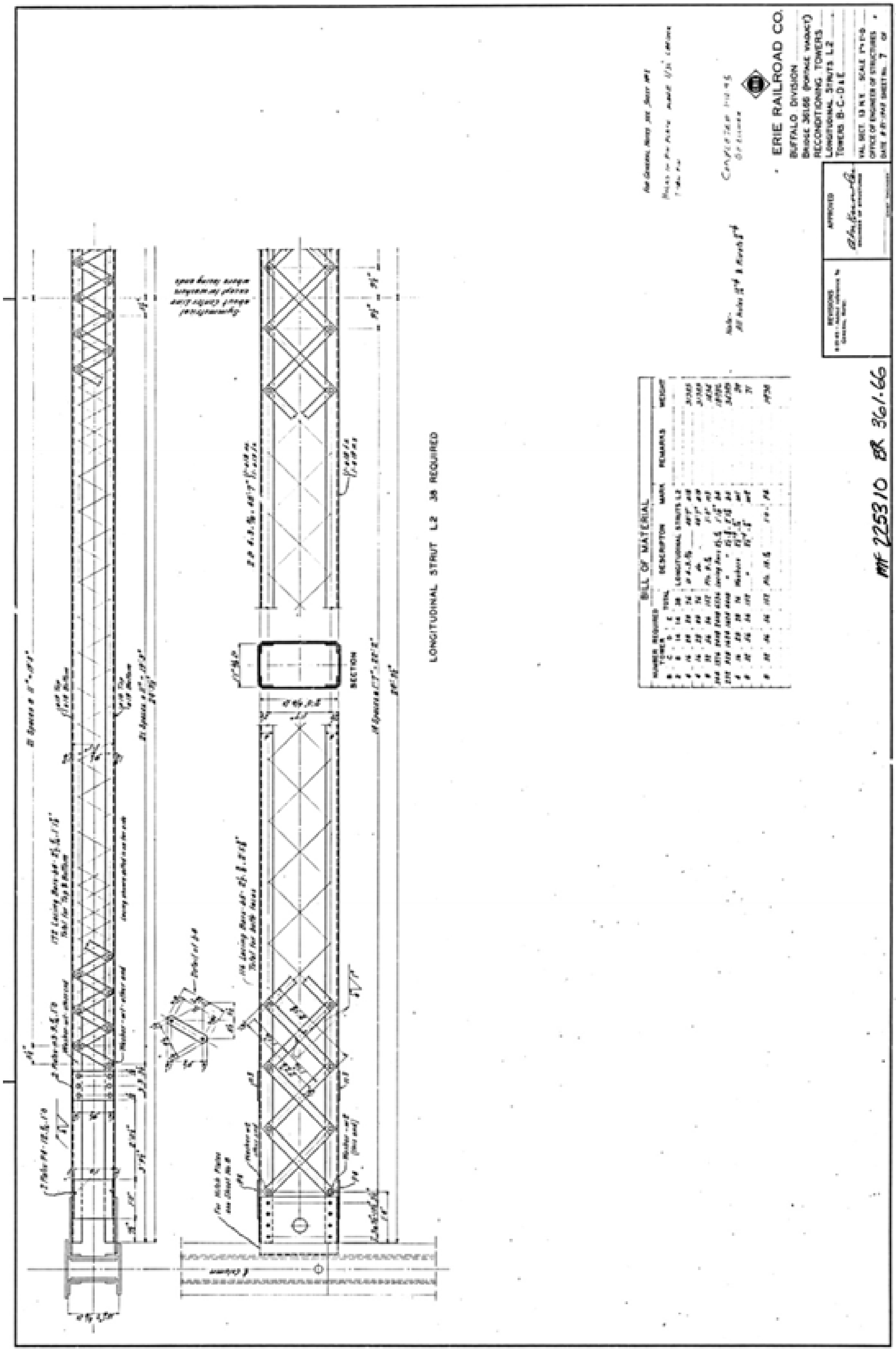


Figure 25. Erie Railroad, "Reconditioning Towers: Longitudinal Struts L2, Towers B, C, D and E," August 21, 1943, Drawing No. MF 225310/BR 361.66, Norfolk Southern Railway.

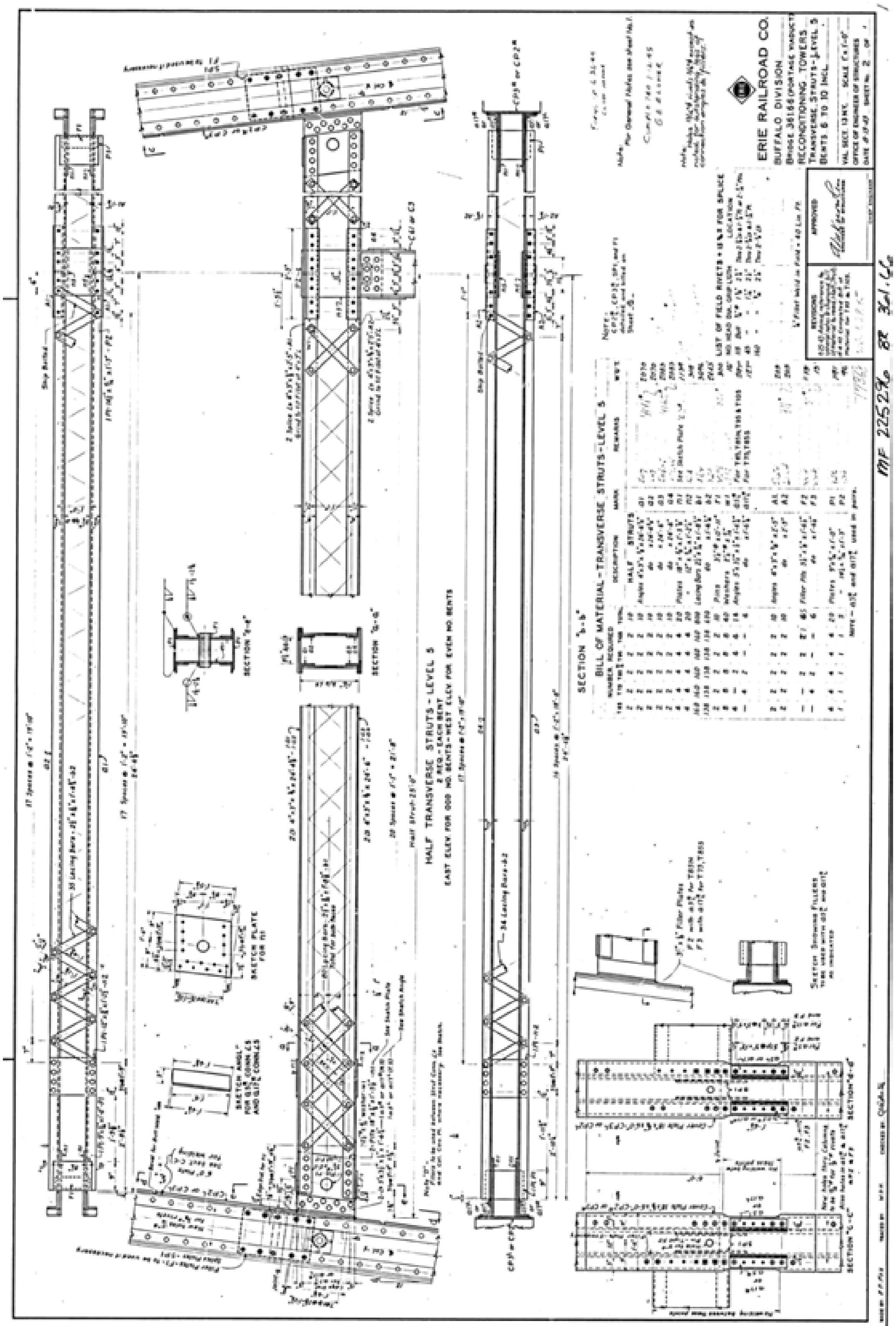


Figure 26. Erie Railroad, "Reconditioning Towers: Transverse Struts, Level 5, Bents 6 to 10 Inclusive," August 19, 1943, Drawing No. MF 225296/BR 361.66, Norfolk Southern Railway.

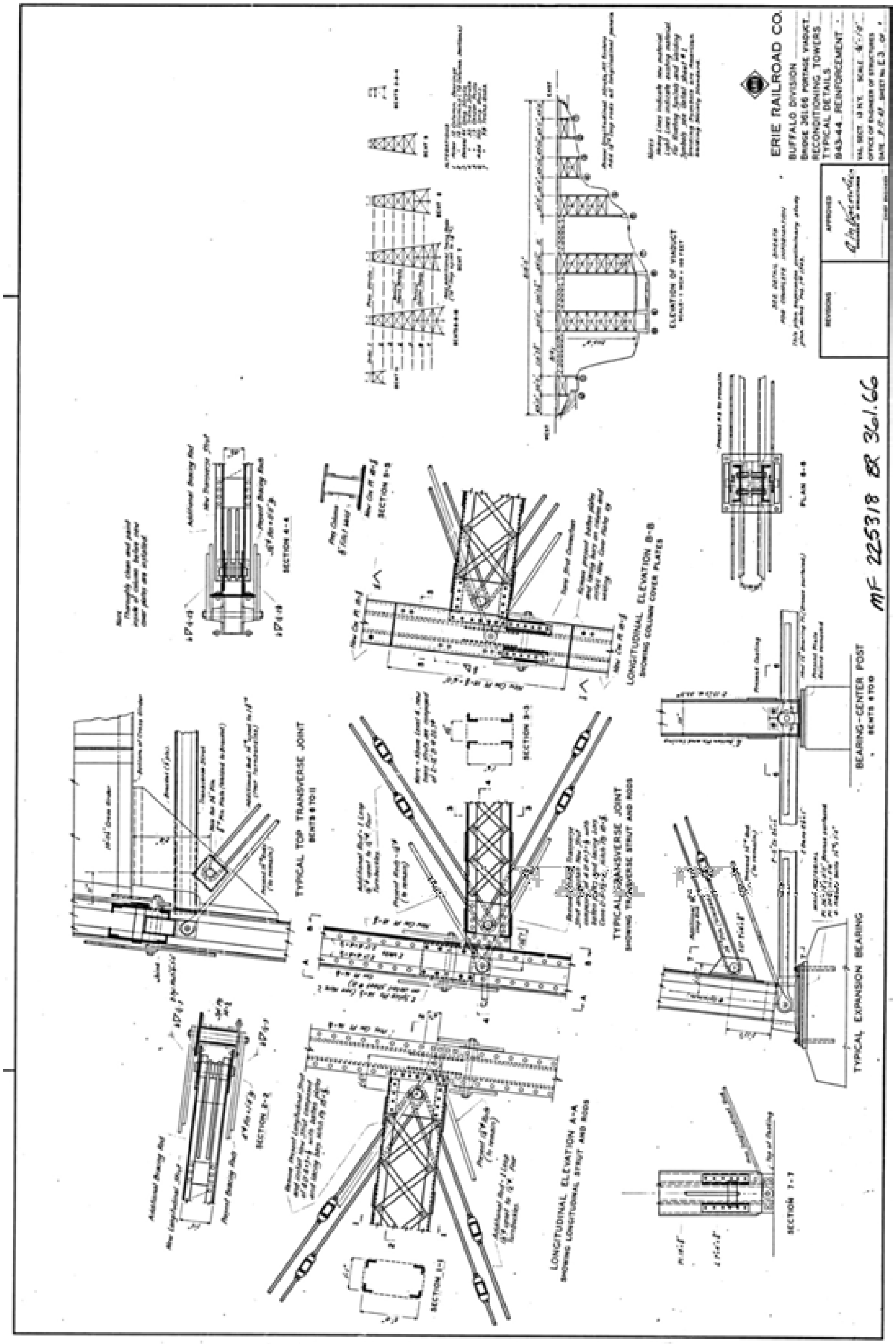


Figure 27. Erie Railroad, "Reconditioning Towers: Typical Details, 1943-1944 Reinforcement," September 17, 1943, Drawing No. MF 225318/BR 361.66, Norfolk Southern Railway.

Figure 28. Double-headed Erie Railroad 2-8-2 Mikado steam locomotives lead the first test train across Portage Viaduct after the tower reconditioning project, September 10, 1944. The Pennsylvania Railroad's Rochester Branch runs under the bridge on the former Genesee Valley Canal alignment. Erie Railroad Photograph, E. S. Evans, Jr. Railway Photo. Matt Kierstead collection.

Figure 29. The Cascade Bridge, a 250' timber arch over Cascade Creek Gorge, near Lanesboro, Pennsylvania. Supported by eight 2'-wide white oak arch ribs, the bridge served the Erie from 1843-1860 when it was replaced by a massive fill. Library of Congress.

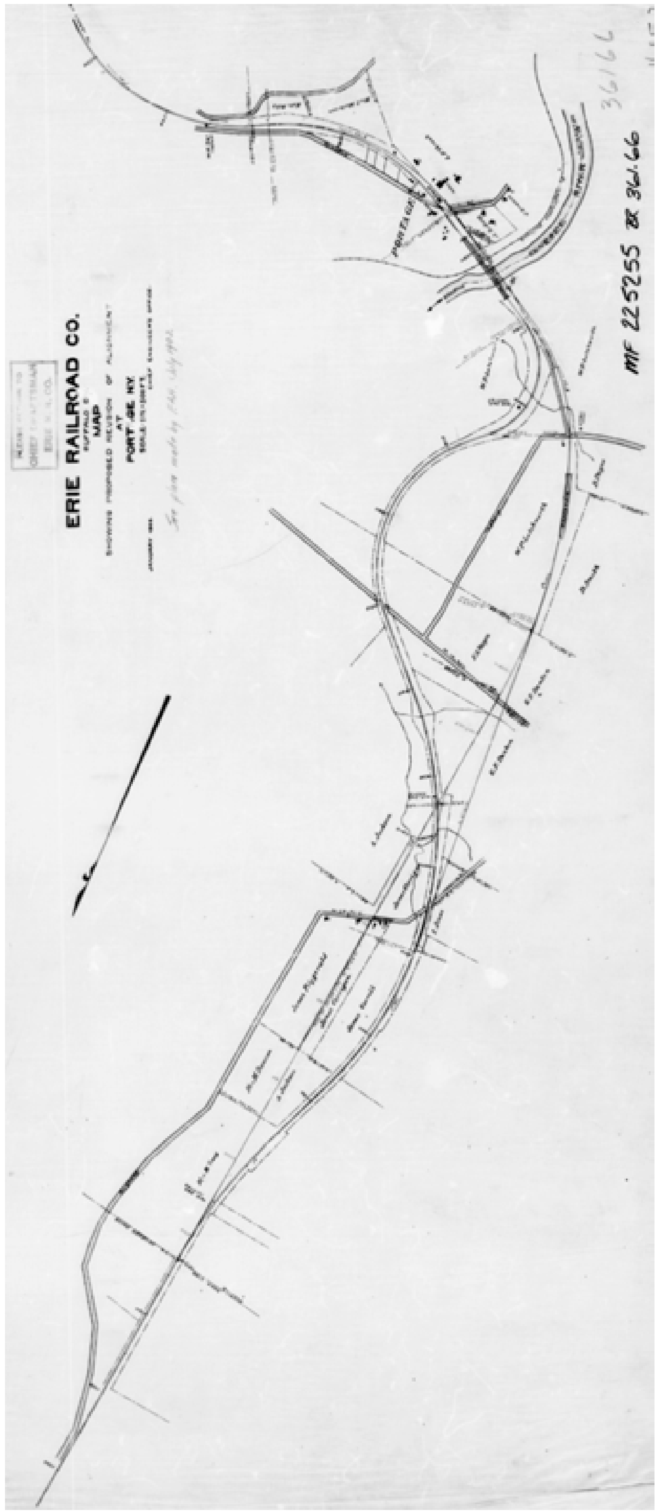


Figure 30. Erie Railroad, "Map Showing Proposed Revision of Alignment at Portage, N.Y," January 1902, Drawing MF 225255/BR 361.66, Norfolk Southern Railway. West of bridge: shows 1851 straight alignment and sinuous 1881 realignment. Also shows fire-fighting reservoir in cut in 1851 alignment.

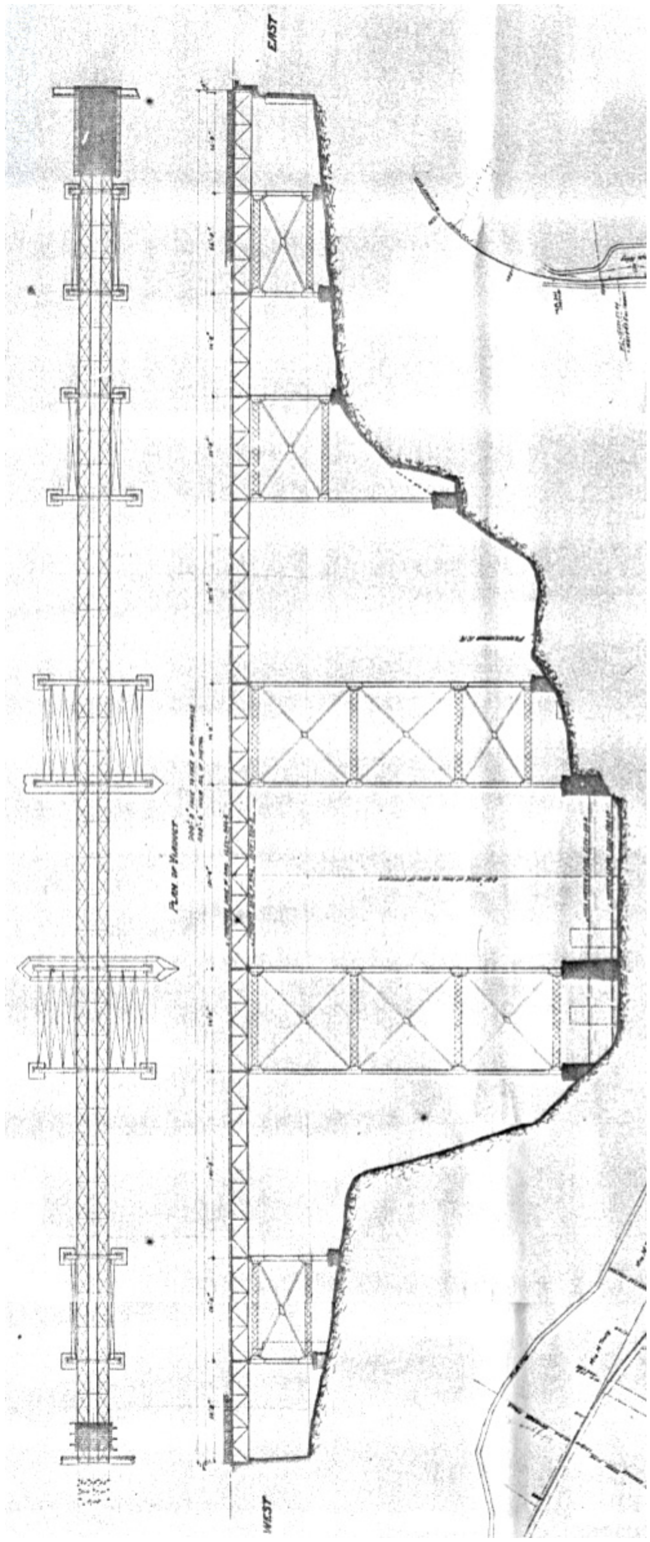


Figure 31. Erie Railroad, "Proposed New Viaduct, and Revision of Alignment & Grades," June 1902, Drawing MF 225275/BR 361.66, Norfolk Southern Railway. Not built. Note planned reduced length, relocated west river tower and piers, and shallow truss spans of equal depth.

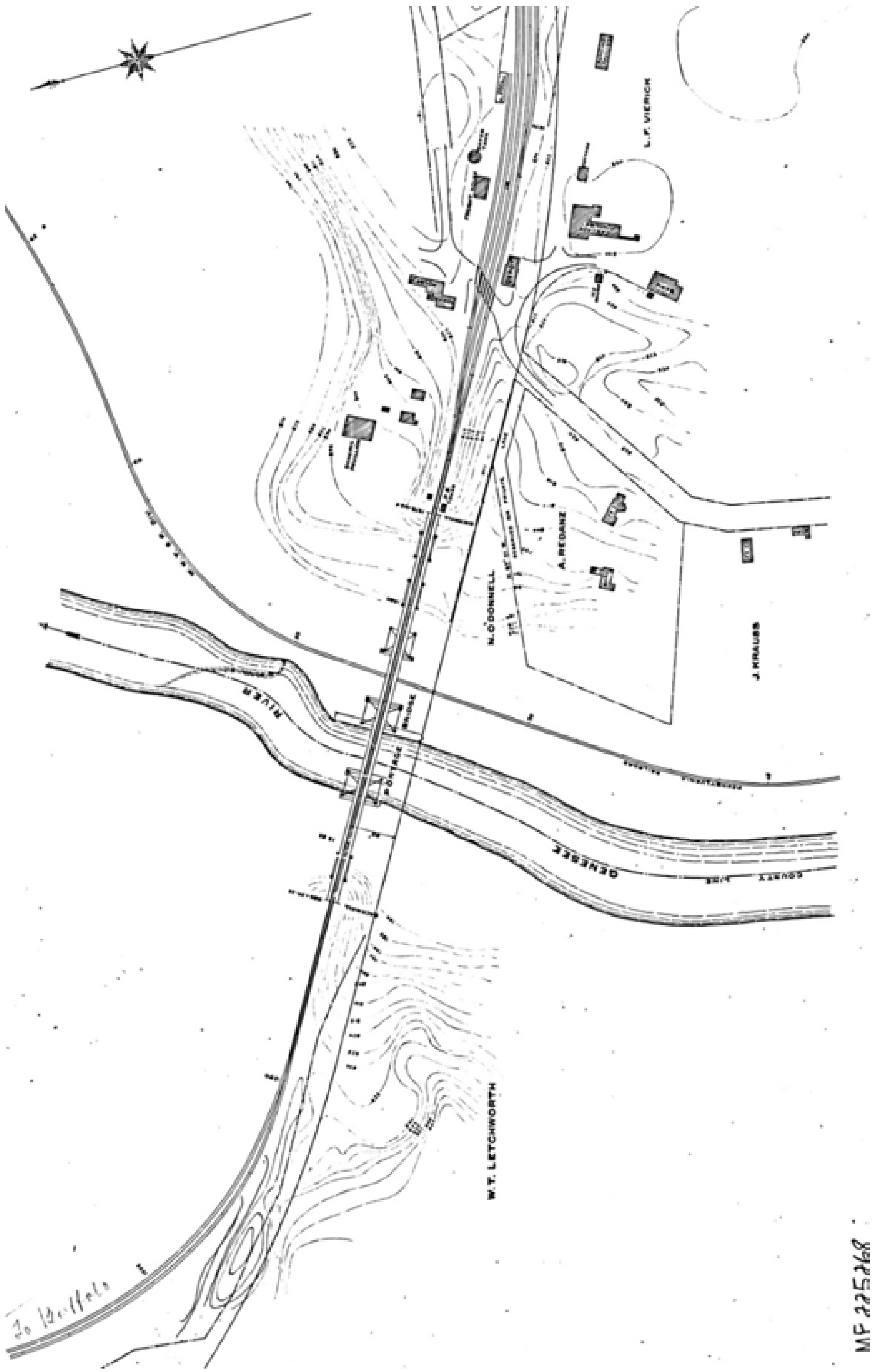


Figure 32. Erie Railroad, "Portage, N.Y.," June 1902, Drawing MF 225268/BR 361.66, Norfolk Southern Railway. Shows station, freight yard, hotels and homes at village of Portage.

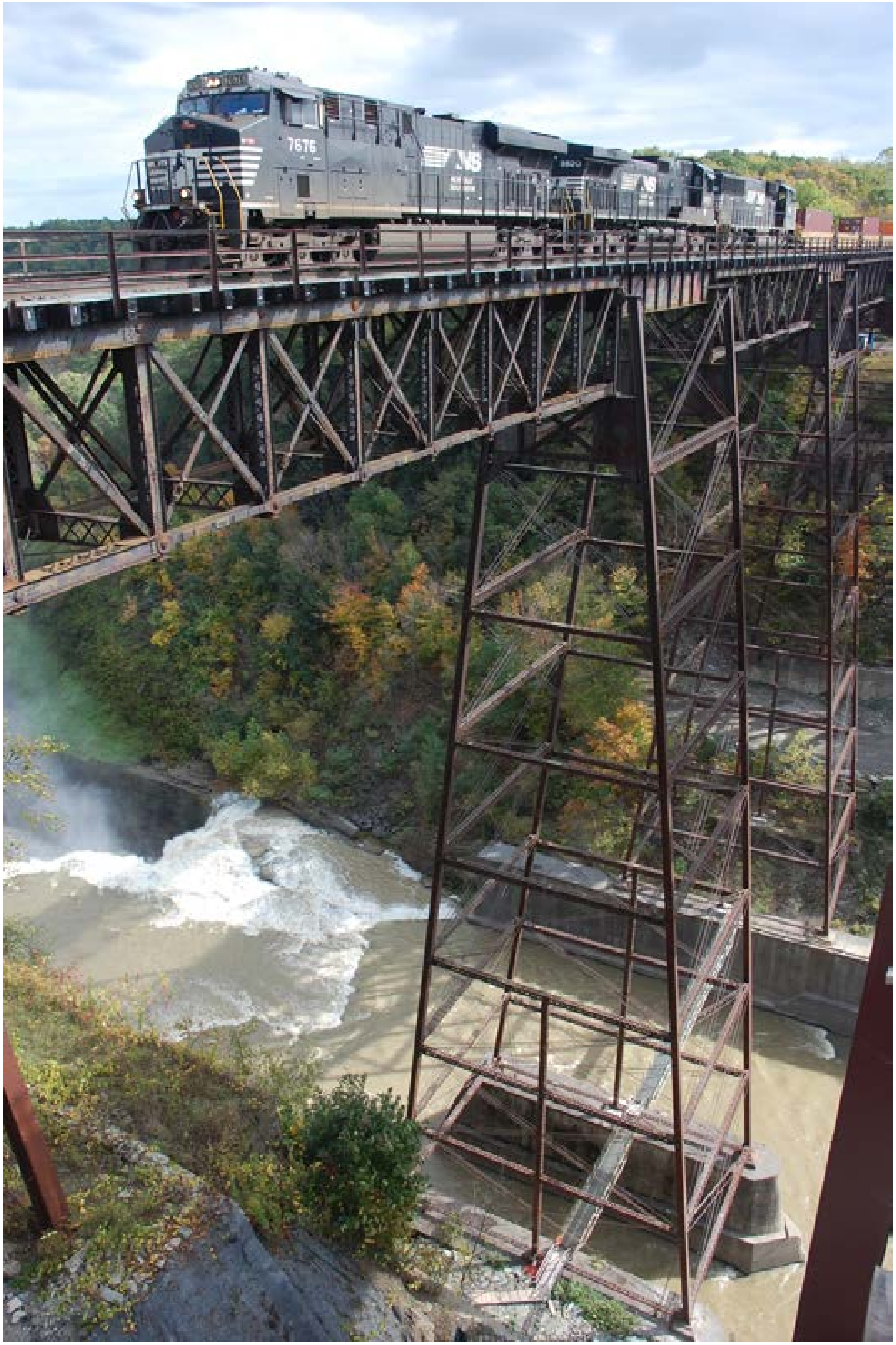


Figure 33. Westbound Norfolk Southern freight train crossing 1875 Portage Viaduct with Genesee River Gorge Upper Falls below, looking east. Photograph by Matt Kierstead, October 13, 2017.

Figure 34. Eastbound Norfolk Southern freight train crossing 1875 Portage Viaduct during construction of the adjacent replacement arch bridge. Aerial photograph by Daniel Spitzer, MD, August 9, 2017.

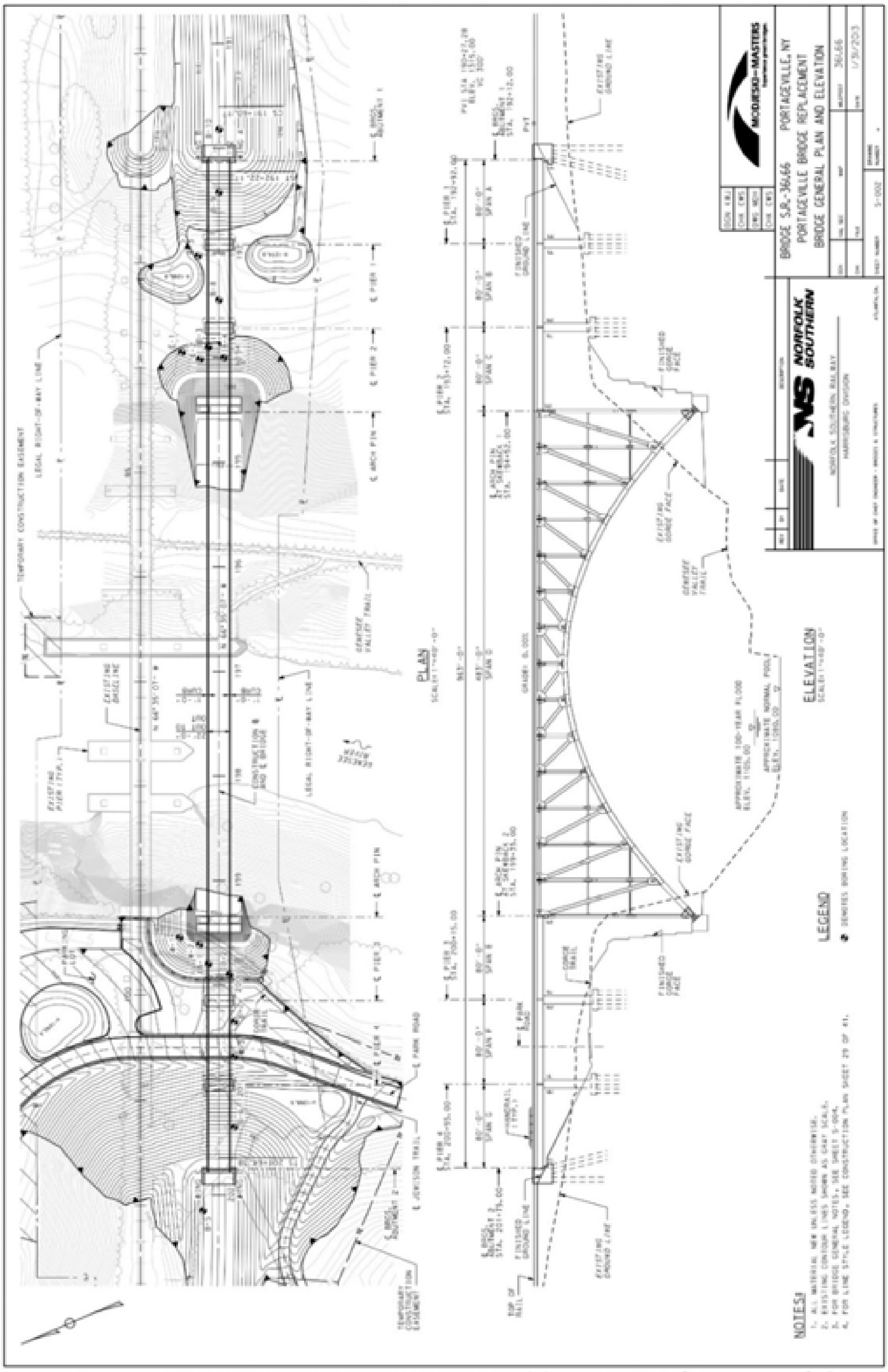


Figure 35. Norfolk Southern Railway, "Bridge S.R.-361.66, Portageville, NY, Portageville Bridge Replacement, Bridge General Plan and Elevation," January 1, 2013, Drawing No. S-002, Norfolk Southern Railway, Norfolk, Virginia. Shows the new "Genesee Arch Bridge" designed by Modjeski & Masters.

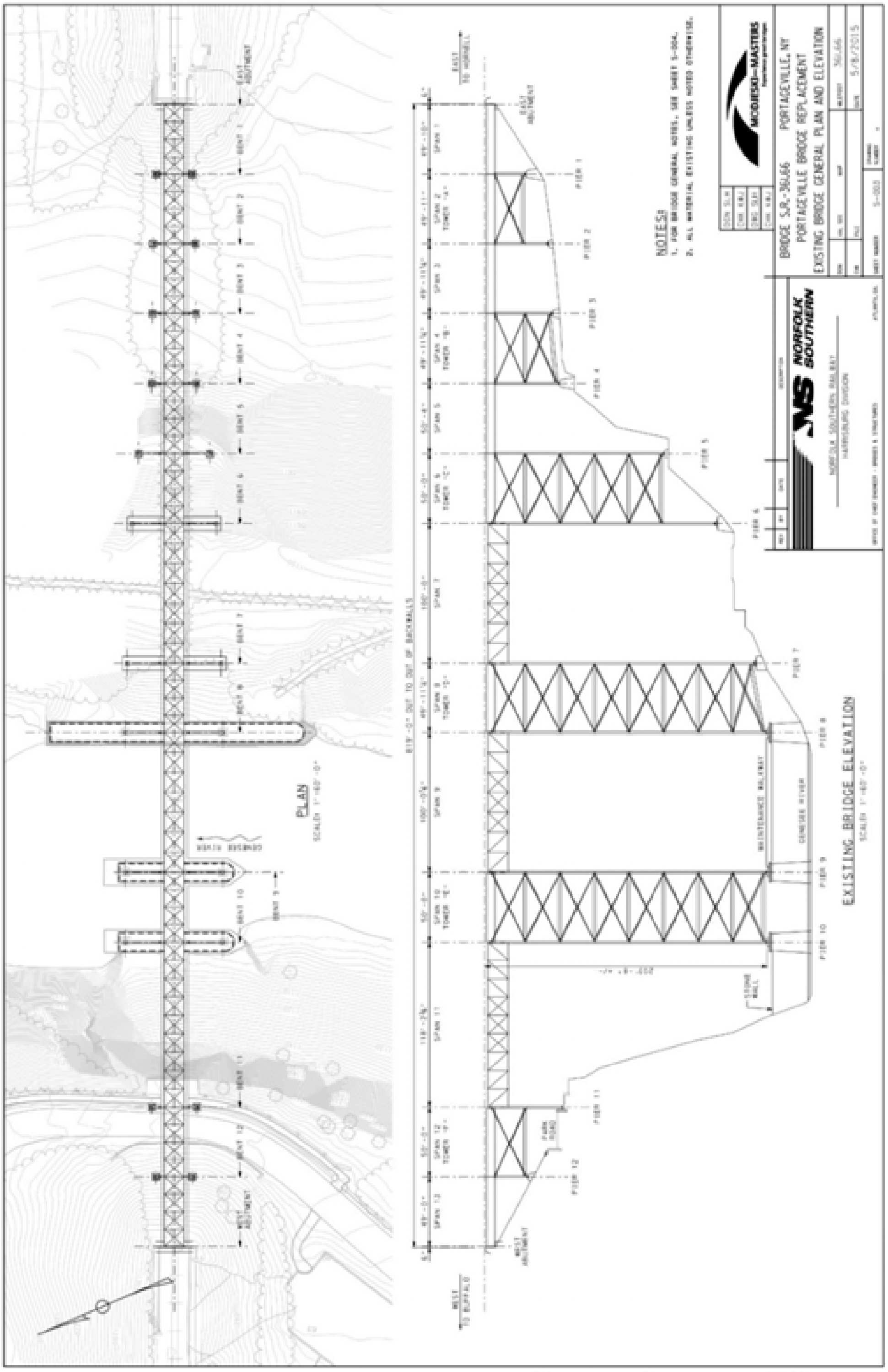


Figure 36. Norfolk Southern Railway, "Bridge S.R.-361.66, Portageville, NY, Portageville Bridge Replacement, Existing Bridge General Plan and Elevation," May 8, 2015, Drawing No. S-003, Norfolk Southern Railway, Norfolk, Virginia. Shows Portage Viaduct existing conditions prior to demolition.

ERIE RAILWAY, BUFFALO DIVISION, BRIDGE 361.66 HAER NY-54
(Portage Viaduct) *HAER NY,61-PORT,1-*
Spanning Genesee River, 0.6 miles west of State Route 436
Portageville vicinity
Wyoming County
New York

PHOTOGRAPHS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001

HAER
NY
51-PORVI,
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HISTORIC AMERICAN ENGINEERING RECORD

INDEX TO PHOTOGRAPHS

Erie Railway: Buffalo Division, Bridge 361.66 (Portage Viaduct)
Spanning Genesee River Valley 0.6 mi. W of State Rt. 436
Portageville
Wyoming County
New York

HAER No. NY-54

Portageville,
17.742160.4717900

Documentation: 5 aerial photos (1971)
2 photocopies of photos of the original and second bridge, 19th century

Photos Nos. NY-54-1 to 5 taken by Jack Boucher, July 1971

NY-54-1 GENERAL VIEW OF THE BRIDGE

NY-54-2 GENERAL VIEW OF THE BRIDGE, CLOSER

NY-54-3 VIEW OF TRAIN TRACKAGE ON BRIDGE

NY-54-4 VIEW OF TRAIN TRACKAGE AND PIERS

NY-54-5 DETAIL VIEW OF PIERS

Photocopies:

NY-54-6 PHOTOCOPY OF 19th CENTURY PHOTO OF THE ORIGINAL BRIDGE, courtesy of Erie Railway Company

NY-54-7 PHOTOCOPY OF JULY 31, 1875 PHOTO OF TRIAL RUN OF THE SECOND BRIDGE, courtesy of Erie Railway Company

HISTORIC AMERICAN ENGINEERING RECORD

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ADDENDUM TO: HAER NY-54
ERIE RAILWAY, BUFFALO DIVISION, BRIDGE 361.66
(Portage Viaduct)
Genesee River, State Route 436
Portageville vicinity
Wyoming County
New York

Photographs HAER NY-54-1 through NY-54-7 were previously transmitted to the Library of Congress.

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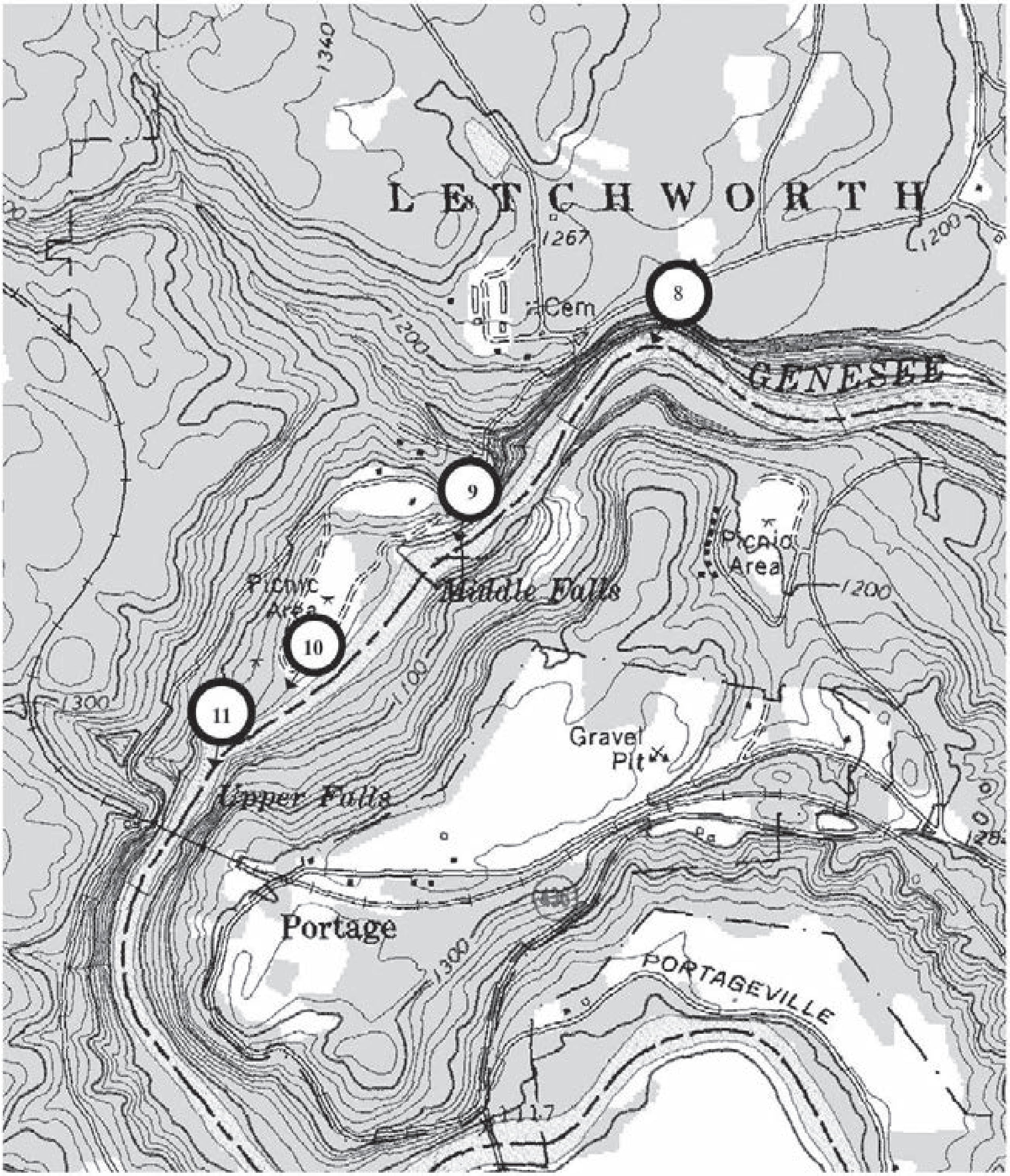
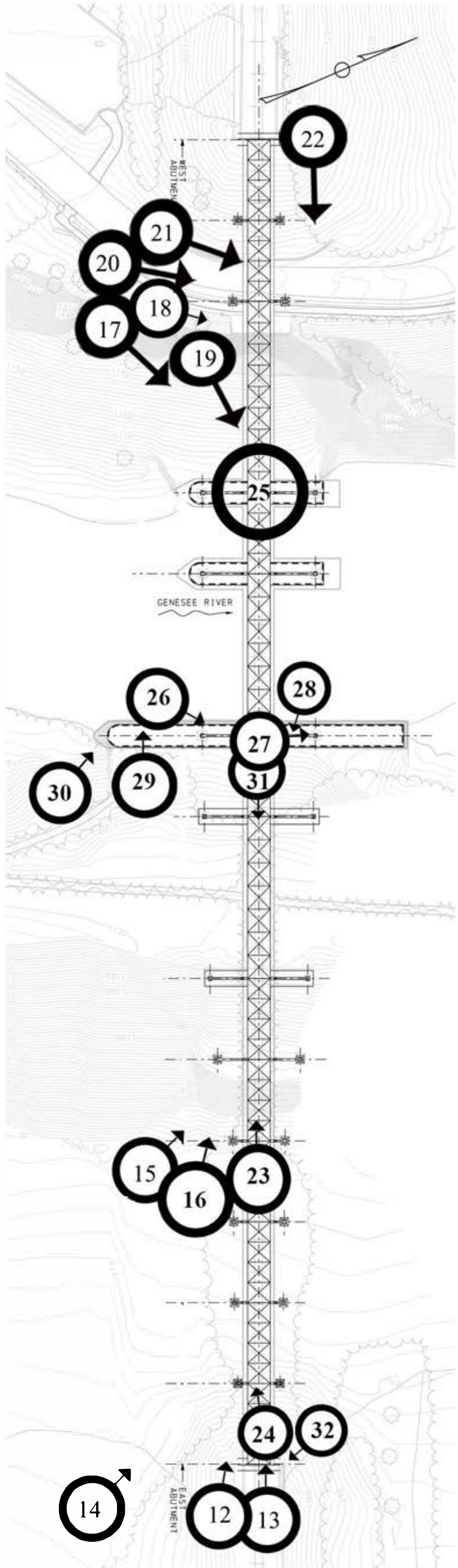
Michael Froio, photographer, April 2015

NY-54-8	Distant view of viaduct showing context of Letchworth State Park; from Inspiration Point, looking southwest.
NY-54-9	General contextual view from Middle Falls of the Genesee River; looking south.
NY-54-10	North side of viaduct at Upper Falls showing towers (left to right) C, D and E; looking southwest.
NY-54-11	North side of viaduct at Upper Falls, showing towers (left to right) B, C, D and E; looking south.
NY-54-12	Oblique view from east end of viaduct with Norfolk Southern freight train passing over. New concrete east abutment is in foreground. Genesee River Gorge west rim is in distance. Trees to the south of viaduct have been cleared for new bridge construction; looking northwest.
NY-54-13	View across viaduct deck from east abutment, showing (outside to inside) railings, pedestrian walkway decks, ties, rails, and guide rails; looking northwest.
NY-54-14	Oblique view of south side of viaduct; looking northwest.
NY-54-15	Oblique view of south side of viaduct, showing towers (left to right) F, E, D, and C; and masonry piers for bents (from left to right) 10, 9, and 8; looking northwest.
NY-54-16	Oblique view of south side of viaduct, showing towers (left to right) F, E, C and D (partial); and masonry piers for bents (left to right) 10, 9, and 8; looking northwest.

NY-54-17	Oblique view of south side of viaduct, showing towers (left to right) E through A; looking east.
NY-54-18	Oblique view of south side of viaduct, showing span 11 (deck truss) at left, and towers (left to right) F, E, D and C (partial), looking northeast.
NY-54-19	Oblique view of south side and underside of viaduct, showing span 11 (deck truss) at upper left, and towers (left to right) E through A and masonry pier for bent 8 at lower right, looking east.
NY-54-20	Broadside view of south side of west of viaduct, showing (left to right, bent 12, span 7 (deck girder), tower F over park access road, and span 6 (deck truss) over Gorge Trail, looking north.
NY-54-21	Detail of south side of west end of viaduct, showing tower F over park access road. Note masonry pier for original 1851 wood trestle tower incorporated in roadway's west retaining wall in center; looking north.
NY-54-22	Oblique view of north side of viaduct from west abutment, showing tower F over Letchworth State Park access road including posts, struts, diagonal bracing and concrete pier of bent 12, looking southeast.
NY-54-23	Longitudinal view along underside of viaduct from east end, showing tower 2 struts and bracing in foreground, looking northwest.
NY-54-24	Detail view of underside of span 1 deck girder, showing lateral bracing and detail of top of bent 1, looking west.
NY-54-25	Single perspective view of tower E, showing posts, struts, sway bracing, and deck structure, looking up from top of pier.
NY-54-26	Detail view of tower D, bent 8, south post, showing bottom of post and pier bearing, strut and sway brace connections, and 1875 construction date, looking northeast.
NY-54-27	Detail view of tower D, bent 8, north post, showing bottom of post and pier bearing, and strut connections, looking north.
NY-54-28	Detail view of tower D, bent 8, center post, showing bottom of post and pier bearing, and strut connections, and sway brace connections, looking northeast.
NY-54-29	View of south side of viaduct from east bank of Genesee River Gorge, showing (front to back) piers 8, 9, and 10; shotcrete-stabilized west gorge wall, masonry pier for original 1851 wood trestle; and railing for the Gorge Trail; and west abutment; looking northwest.
NY-54-30	Detail view of south side of viaduct from east bank of Genesee River Gorge, showing (front to back) pier 8 and part of tower D, piers 9 and 10 with base of tower E. Note modern catwalk between piers, looking northwest.

NY-54-31	Detail view under tower D, pier 7, showing exposed fire-damaged masonry from original 1851 pier; looking southeast.
NY-54-32	Detail view of east abutment showing east end of span 1 deck girder resting on 1875 stone abutment with modern concrete alterations, looking north.


LETCHWORTH
1267
Cem
1200
8
GENESEE
9
Picnic Area
Middle Falls
Picnic Area
1200
10
1100
11
1300
Gravel Pit
Upper Falls
Portage
436
1300
PORTAGEVILLE
1117
1340


WEST ABUTMENT
GENESEE RIVER
EAST ABUTMENT
22
21
20
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HISTORIC AMERICAN ENGINEERING RECORD

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ADDENDUM TO: HAER NY-54
ERIE RAILWAY, BUFFALO DIVISION, BRIDGE 361.66
(Portage Viaduct)
Spanning Genesee River, 0.6 miles west of State Route 436
Portageville vicinity
Wyoming County
New York

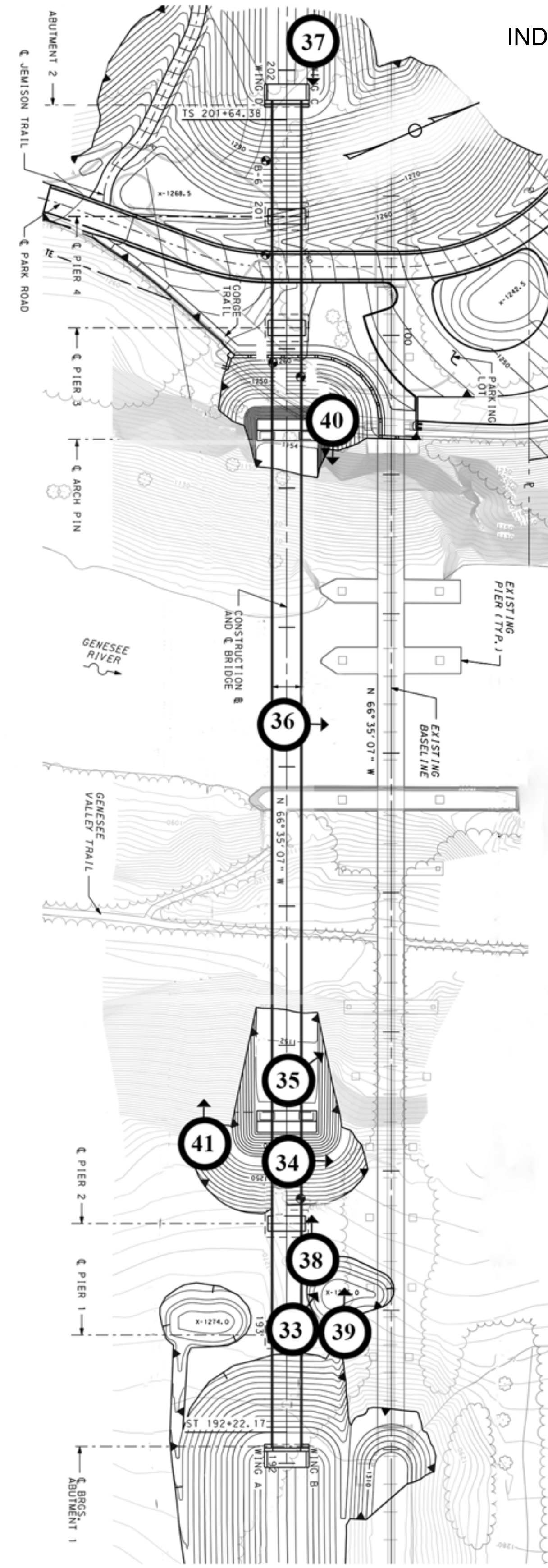
Photographs HAER NY-54-1 through HAER NY-54-32 were previously transmitted to the Library of Congress.

INDEX TO BLACK AND WHITE PHOTOGRAPHS

Michael Froio, photographer, October 2017

NY-54-33	Oblique view of viaduct from new railroad bridge showing (front to back) deck girder spans 3-6; tower B (detailing bent posts 3 and 4, struts, diagonal bracing and concrete piers); and partial view of tower C; looking northwest.
NY-54-34	Broadside detail view of tower B and span 4 from new railroad bridge showing railing, ties, bent posts 3 and 4, struts and diagonal bracing, looking northeast.
NY-54-35	Oblique detail view of span 7 deck truss from new railroad bridge showing railing, ties, (front to back) spans 6, 7, 8, and deck truss support headers on the opposed inner bents 6 and 7 of towers C and D, looking northwest.
NY-54-36	Broadside detail view of span 9 deck truss from new railroad bridge showing railing, ties, deck truss and truss support header on the east face of tower E bent 9, with Genesee River Gorge Upper Falls below, looking northeast.
NY-54-37	Longitudinal view across Genesee River Gorge along north edge of new railroad bridge deck from new bridge west abutment, with Portage Viaduct at left, looking southeast.
NY-54-38	Longitudinal view across Genesee River Gorge along north face of new railroad bridge with Portage Viaduct at right, looking northwest.
NY-54-39	Longitudinal view across Genesee River Gorge between the bridges with new railroad bridge at left and Portage Viaduct at right, looking northwest.

NY-54-40	Longitudinal view across Genesee River Gorge between the bridges with Portage Viaduct at left and new railroad bridge at right, looking southeast.
NY-54-41	Longitudinal view across Genesee River Gorge with new railroad bridge arch above and Portage Viaduct beyond at right, looking northwest.


37
40
36
35
41
34
38
33
39
ABUTMENT 2
℄ JEMISON TRAIL
℄ PARK ROAD
℄ PIER 4
GORGE TRAIL
℄ PIER 3
PARKING LOT
℄ ARCH PIN
GENESEE RIVER
CONSTRUCTION ℄ AND ℄ BRIDGE
EXISTING PIER (TYP.)
EXISTING BASELINE
N 66°35'07" W
GENESEE VALLEY TRAIL
℄ PIER 2
℄ PIER 1
℄ BRGS. ABUTMENT 1
TS 201+64.38
ST 192+22.17
WING A
WING B

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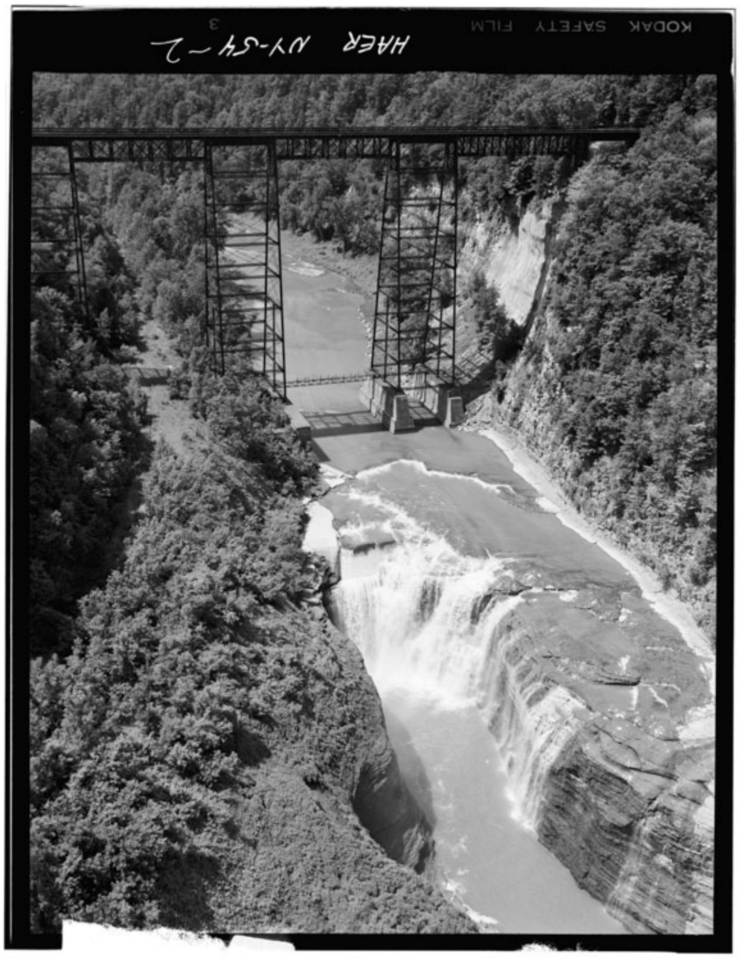

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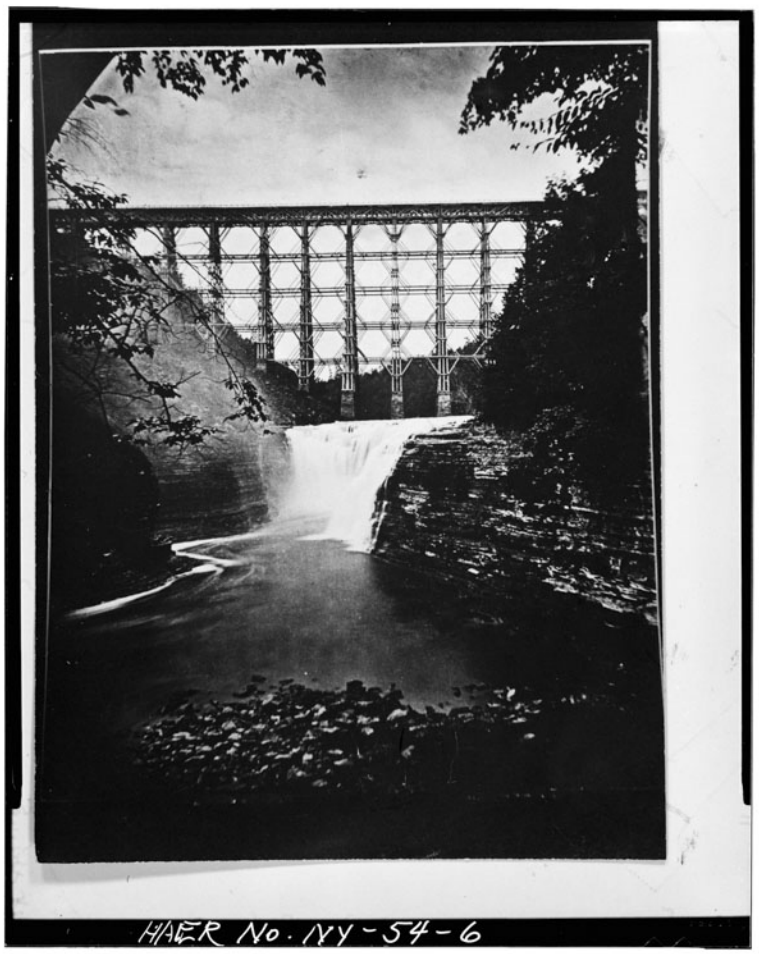

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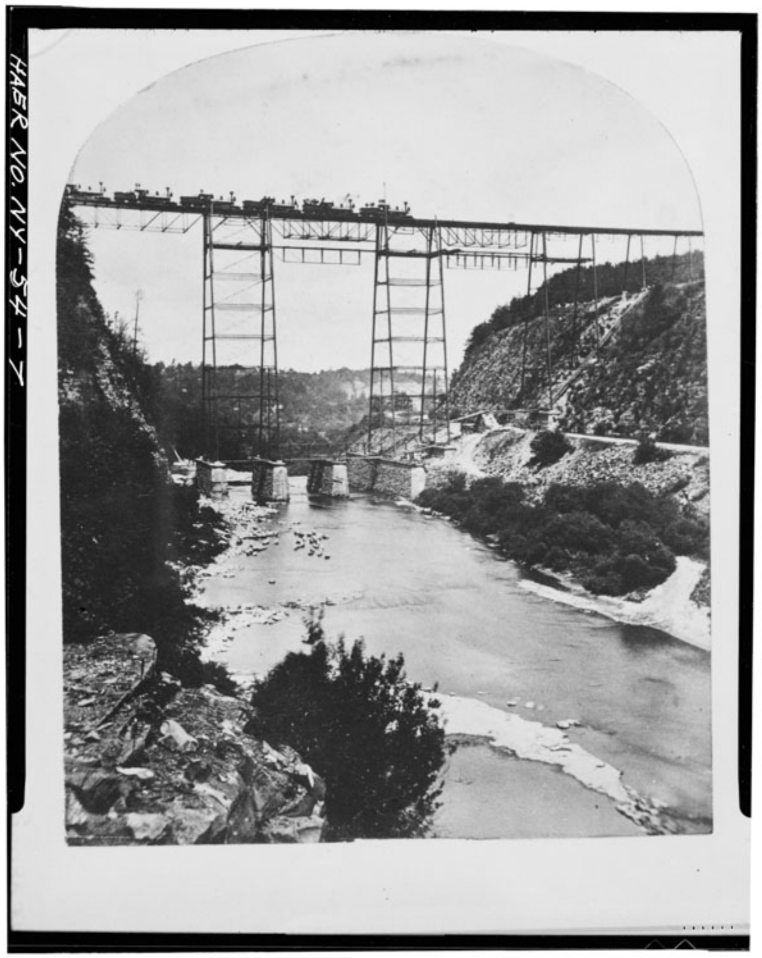

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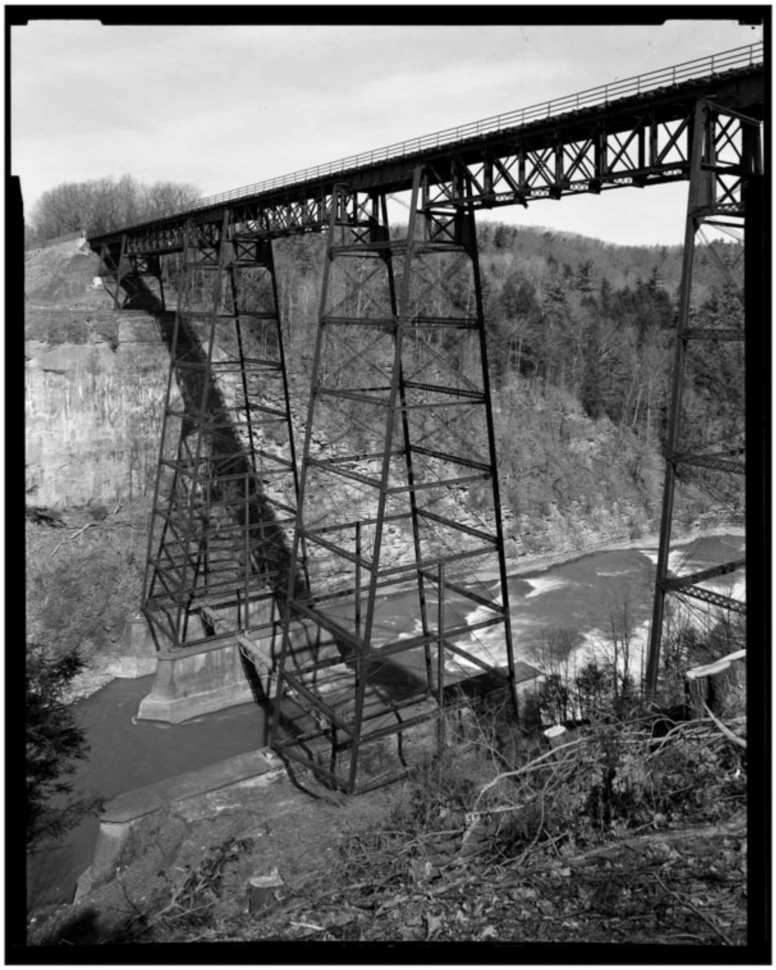

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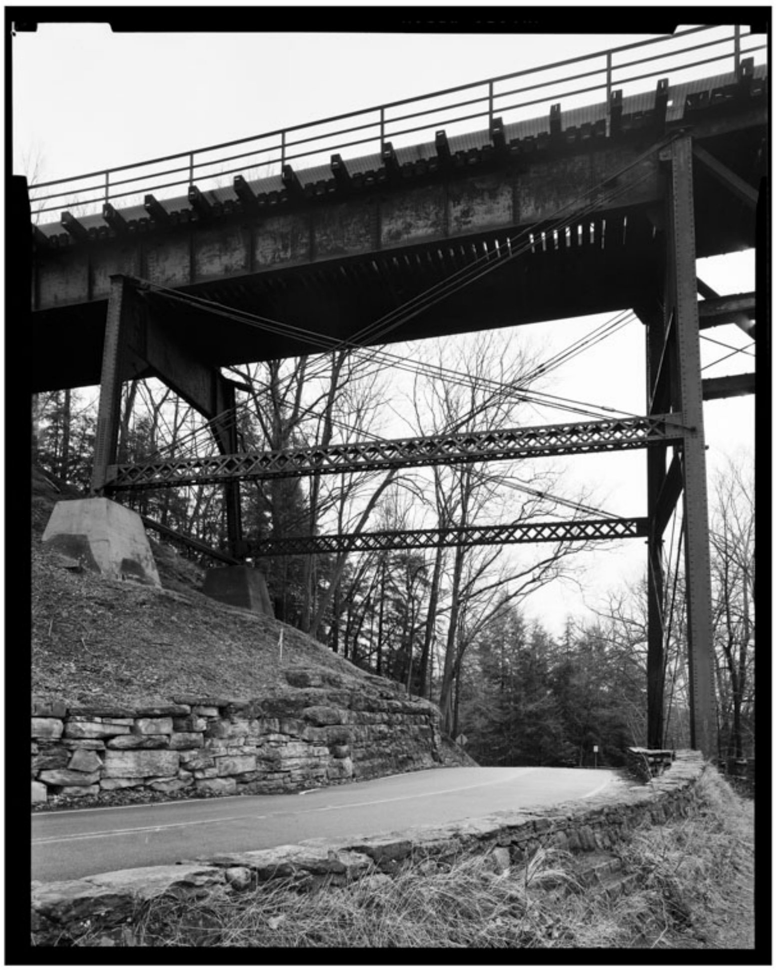

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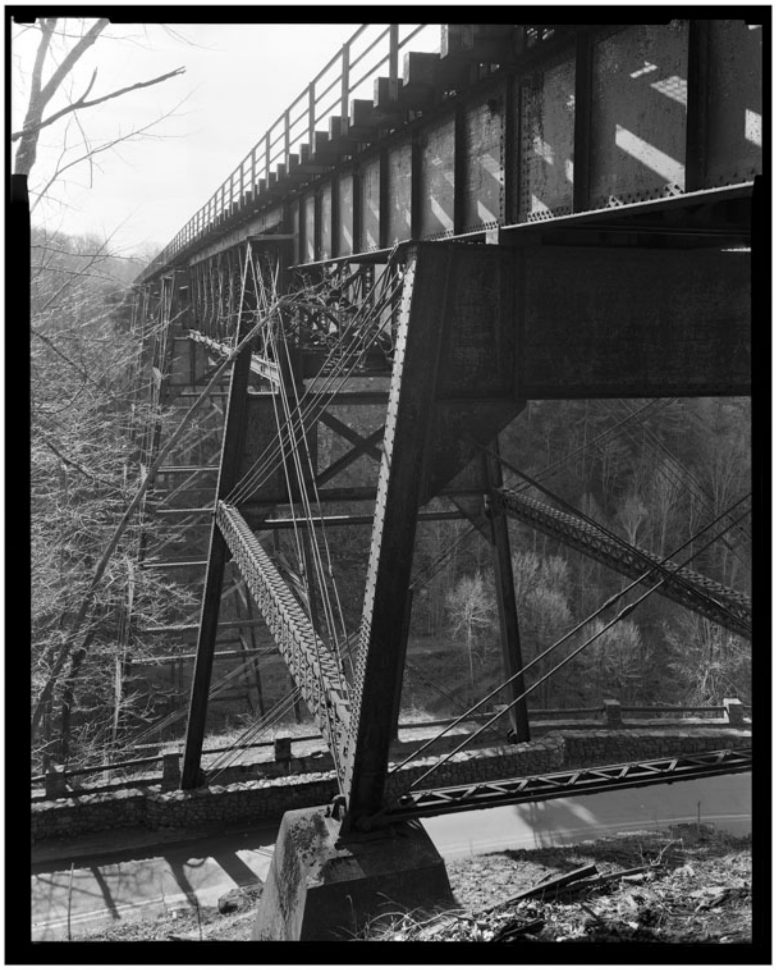

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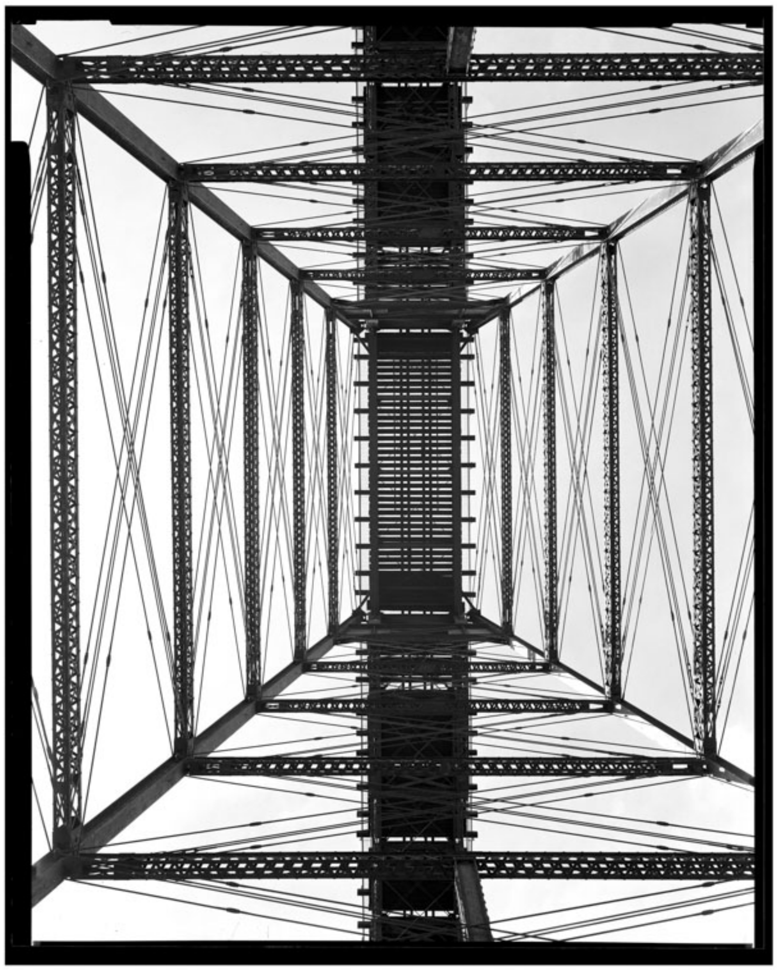

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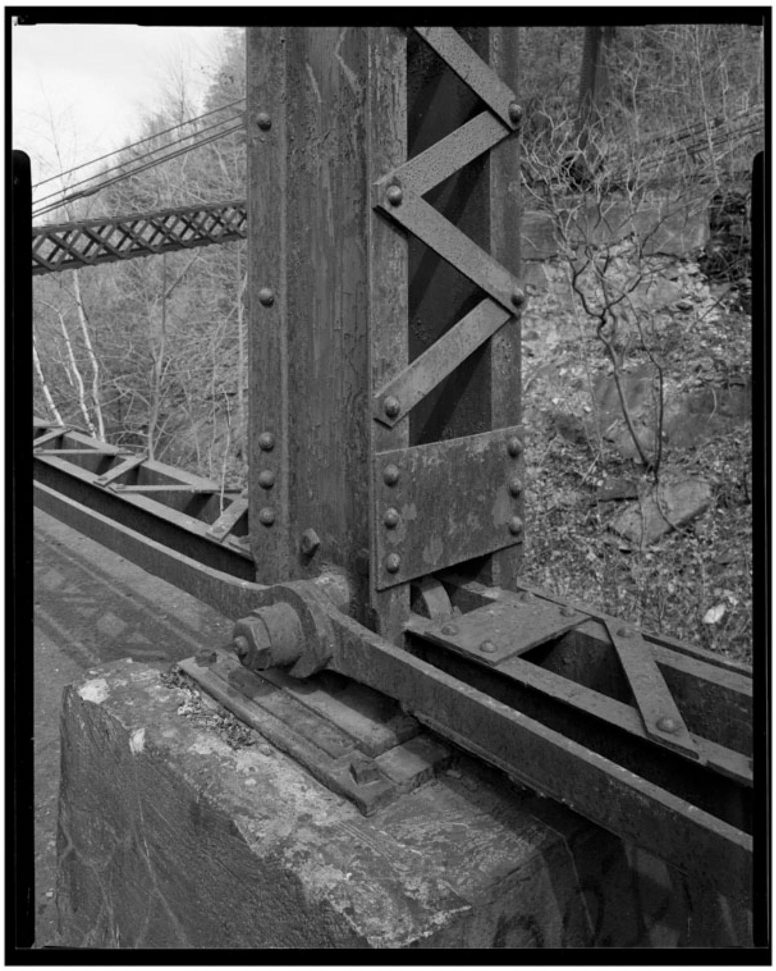

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