Lower Merrimack River Bridges

A review of the bridges along a fairly industrialized stretch of a river provides a unique way to portray the development and range of modern bridge design and construction.

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This article is a photo essay describing 14 of the present 24 bridges that cross the Merrimack River in Massachusetts, starting in Tyngsborough and continuing to Newburyport. The bridges span not just the river, but over a hundred years of bridge design and construction history. They provide a visual record of the different methods and approaches that have been used by bridge engineers over the decades.

Originating in the White Mountains of New Hampshire, the Merrimack River flows 110 miles on its way to the sea. The last 50 miles, known as the Lower Merrimack, begins at the Massachusetts state border at Tyngsborough and winds through a dozen communities in northeastern Massachusetts before reaching the Atlantic Ocean at Newburyport.

J.W. Meader, in his book, *The Merrimack River, Its Source and Tributaries* (1869), provided a vivid description of the river:

> *The Merrimack, dotted here and there with a variety of craft, from the light and trembling skiff to the heavy gondola, and the still more imposing and majestic moving ocean craft, with their broad, white sails and tall masts overshadowing the water, and, spanned with its bridges, flows calmly at its base, not in straight, monotonous course, but with a gentle meandering, of which the eye can never tire.*

Early settlers in the Merrimack Valley relied on this major waterway for sustenance and access to the interior from the sea, but the river remained an impediment to overland travel throughout the Colonial period, with ferries being the only means of crossing the river. By the close of the War of Independence, there were at least nine ferries between Tyngsborough and Newburyport. However, in an age of increasing industrialization, the need for a more permanent and reliable means of crossing the river grew stronger.

In 1792, the Massachusetts General Court authorized construction of the first bridge across the Merrimack River. By 1800, there were five bridges; by 1900, fifteen; today, there are twenty-four. At least 55 different bridges have spanned the Lower Merrimack River over the last 200 years, and half of the present bridges are the third or fourth generation to span their respective locations. The present structures range in age from 17 to 117 years old, incorporate a wide variety of materials, represent nearly every major bridge type and reflect the evolution

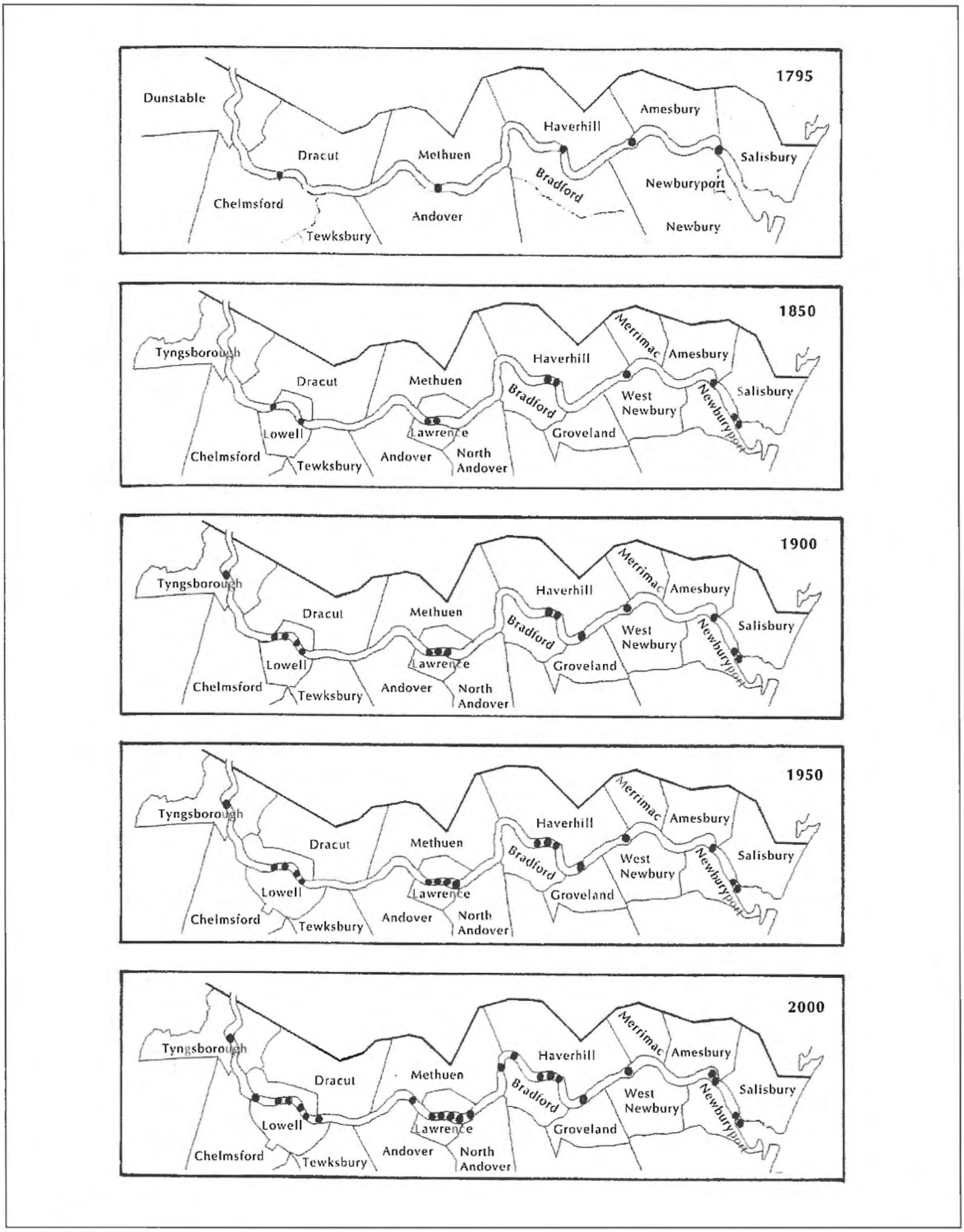
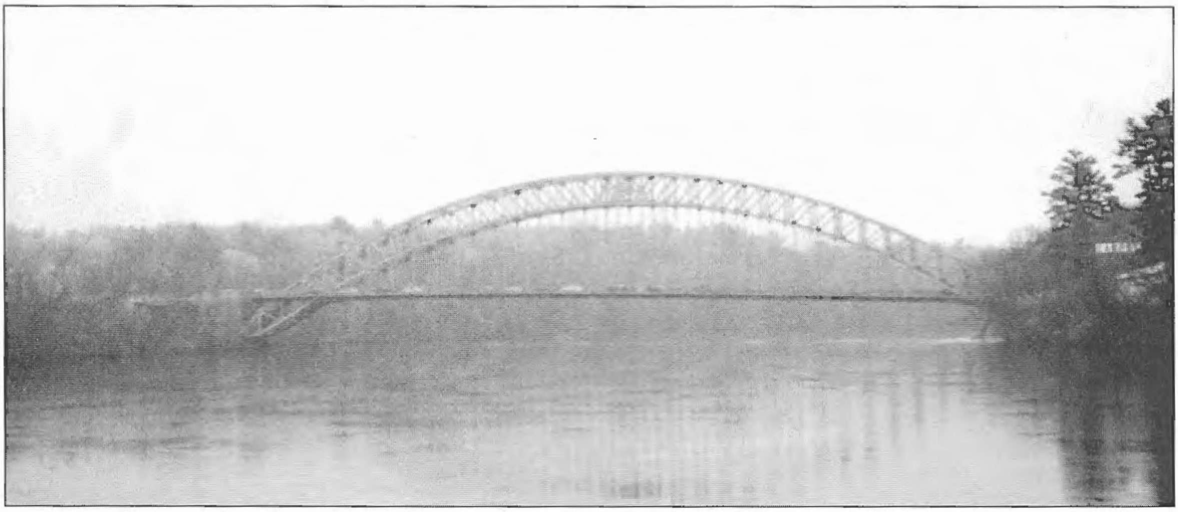


FIGURE 1. Chronology of bridge locations on the Lower Merrimac River.

of engineering technology over the past two centuries. Although most have undergone repairs and rehabilitation over the years, nearly all retain their original appearance, and all but one remain in active use. Figure 1 presents a chronology of bridge locations on the river.



Tyngsborough Bridge, Route 113, Tyngsborough, 1930

For nearly 150 years, beginning in 1728, the only way to cross the Merrimack River between Nashua and Lowell was by ferry. In 1871, the Massachusetts State Legislature authorized the Middlesex County Commissioners to lay out a highway and build a bridge across the Merrimack at Tyngsborough. The highway was constructed in 1872, and a four-span, iron Whipple truss was erected at this location in 1873. That bridge carried heavy vehicular and pedestrian traffic for 57 years until the County Commissioners declared the aging structure unsafe in 1929. In the following year, the Massachusetts Department of Public Works constructed the present 547-foot steel trussed-rib through arch. The bridge was designed and erected as a statically determinate three-hinged steel arch, and made more rigid upon completion by fixing the crown hinge. This design became a popular one for highway bridges around the turn of the century.

The history of metal arch bridges began, however, in 1779, when the world's first cast iron arch was erected near Coalbrookdale, England. A half-century later, the metal arch was tested on a modest scale in the United States, with Captain Richard Delafield's (1798-1873) Dunlap's Creek Bridge (1839) on the National Road at Brownsville, Pennsylvania, and General Montgomery Meigs's (1816-1892) Rock Creek aqueduct-bridge (1858) in Washington, D.C. Although both structures were successful, metal arch bridges remained a novelty, in part because of the difficulty of analyzing stresses in both fixed and two-hinged arches. The development of the three-hinged arch in 1870, along with the introduction of structural steel and its pioneering use in James Eads's (1820-1887) magnificent arch bridge (1874) across the Mississippi at St. Louis, stimulated the metal arch bridge's rise in popularity in the late nineteenth century. After the beginning of the twentieth century, this graceful and compelling arch form was often chosen for both its structural qualities and aesthetic appeal, particularly for long-span bridges at highly visible locations.

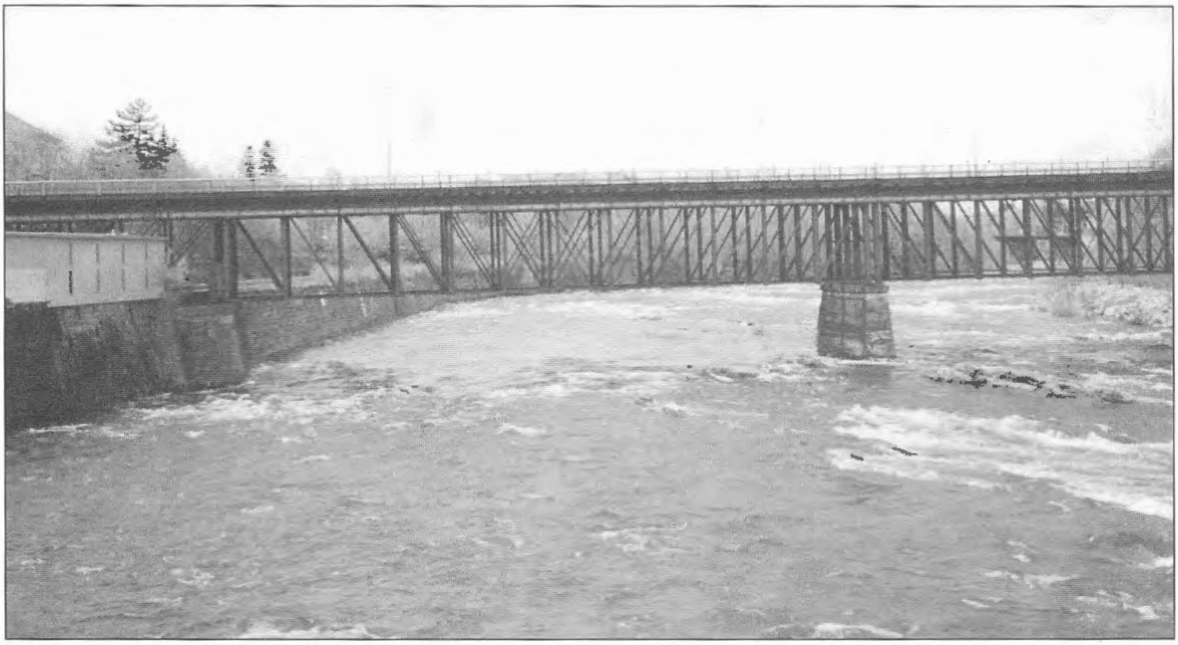
The Tyngsborough Bridge was contemporaneous with the great steel arch bridges at Bayonne (1931), Sydney (1932) and Pittsburgh (1932), but its design and scale most closely resemble the 540-foot Bellows Falls Arch Bridge (1905-1982), which was the longest steel through arch bridge in the United States when it was completed. Nationally renowned structural engineer J.R. Worcester (1860-1943) designed the latter bridge and was the consulting engineer who ultimately recommended replacement of the old Whipple truss structure at Tyngsborough. The Tyngsborough Bridge is the only single-span bridge on the Lower Merrimack, and has the fifth-longest main span of all bridges listed in the MassHighway statewide bridge database. Plans are currently being studied for the rehabilitation or replacement of this structure to accommodate an increasing flow of highway traffic to and from Route 3.

Rourke Bridge, Wood Street Extension, Lowell, 1982

The Massachusetts Department of Public Works erected this modular-panel steel bridge in 1982 to relieve traffic congestion along the Route 3 corridor at Lowell. The seven-span, two-lane temporary bridge was intended to remain in place for six years while a permanent four-lane bridge was designed and constructed, but the project has been repeatedly delayed by political and budgetary concerns.

Since its construction, the bridge has been heavily used by both vehicles and pedestrians. A sidewalk was added in 1986 and the deck was replaced in 1996. This type of structure, comprised of standardized 5- by 10-foot galvanized steel truss panels, is a modern version of the World War II "Bailey Bridge," introduced in 1941 by British engineer Sir Donald Bailey (1901-1985). Two hundred miles of temporary bridging were built by Allied forces during the war to move troops and equipment, and it has been said that General Dwight D. Eisenhower considered the Bailey Bridge one of the three most important technological developments of the war effort, along with radar and the heavy bomber.

Since World War II, modular panel bridges have become commonplace for both military and civilian applications, particularly for emergency installations or for temporarily detouring traffic while permanent bridges are undergoing repairs or reconstruction. They can be shipped in sections, assembled rapidly, require little maintenance and are reusable. In addition, the span length and carrying capacity requirements for a given span can be easily adjusted by adding or subtracting panels. While sometimes derided as resembling a "giant erector set," panel bridges are intended to be efficient, cost effective and temporary — thus, aesthetic considerations are incidental to their design. Under Chapter 204 of the Acts of 1982, this bridge was named for former Assistant Secretary of Transportation Raymond F. Rourke, and his late son Rep. Timothy M. Rourke, "in recognition of the numerous and outstanding contributions [they made] made to the Commonwealth and the Lowell Area."



Moody Street Bridge (Textile Avenue Bridge), Textile Avenue, Lowell, 1896

This three-span, pin-connected, steel Pratt deck truss was erected by the City of Lowell in 1896, when Moody Street was extended across the river from the city's thriving industrial center to the growing residential neighborhood of Pawtucketville. The bridge was designed by consulting engineer John E. Cheney (1847-1906), who is best known for his career as a bridge engineer for the City of Boston from 1885 to 1906. The deck truss configuration was likely chosen for this site because of its ability to support an exceptionally wide deck without requiring a substantial increase in the size of the floor beams and lateral bracing. This bridge was designed to carry two vehicular lanes, two pedestrian sidewalks and a street railway line.

Although the trusses bear evidence of periodic repairs, the Moody Street Bridge retains much of its structural integrity. However, its most distinguishing aesthetic feature — ornate wrought-iron railings — have been replaced with modern guardrails. According to the MassHighway Historic Bridge Inventory, the Moody Street Bridge is the oldest of five known Pratt deck truss highway bridges in Massachusetts, and also contains two of the longest (180 feet) nineteenth-century metal truss spans in the state. The Pratt truss was patented in 1844 by railroad engineer Thomas W. Pratt (1812-1875) and featured vertical wooden compression members and diagonal iron tension members.

Developed at a time when railroads were placing new demands on bridges and the structural action of trusses was just beginning to be understood, the Pratt truss (along with the Howe and Whipple trusses) heralded the transformation from empirical to scientific bridge design. While the type was not immediately popular, it became so after the Civil War, when, along with other truss types, it was built with all-iron members. The Pratt truss was favored for its straightforward design, strength and adaptability, and by 1870 it had become the standard American truss for moderate spans on both railroads and highways, and remained so well into the twentieth century.

One of the largest and most famous Pratt deck truss bridges is George S. Morison's (1842-1903) Portage Viaduct (1875) across the Genesee River at Portageville, New York. The outstanding qualities of the basic configuration spawned many modifications and subtypes, including the Pennsylvania, Parker, Kellogg, Baltimore, Lenticular and Camelback trusses. At least one-third of the bridges presently spanning the Lower Merrimack utilize some variation of the Pratt truss in their design.

Aiken Street Bridge (Joseph R. Ouellette Bridge), Aiken Street, Lowell, 1883

In 1883, the City of Lowell erected the Aiken Street Bridge to provide a second Merrimack River crossing (the other being Central Bridge) near the city center. This five-span, pin-connected, wrought iron, lenticular through truss bridge features a polygonal upper chord whose outward thrust is perfectly balanced by the inner pull of the lower tension chord. The distinctive double-convex curvilinear (lens-shaped) profile has precedents dating back at least to the early nineteenth century, when British railroad pioneer George Stephenson (1781-1848) built the Gaunless Railway Bridge (1824) with four wrought iron lenticular trussed girders. The form was further developed in the 1840s and 1850s in France, Germany and Britain, where it was used for a variety of innovative spans, including Isambard Kingdom Brunel's (1806-1859) impressive Royal Albert Bridge (1859) at Saltash.

In the United States, patents were granted for lenticular trusses in 1851 and 1855, but the form did not become popular until 1878, when William O. Douglas (b. 1841), of Binghamton, New York, patented an "elliptical bridge truss," and became associated with the Corrugated Metal Company (later the Berlin Iron Bridge Company) of East Berlin, Connecticut. After gaining the exclusive rights to Douglas's patent, the company aggressively marketed the design and by the 1890s had fabricated and erected hundreds of lenticular bridges in the United States. The Aiken Street Bridge is one of about 50 of the company's bridges that have survived to the present.

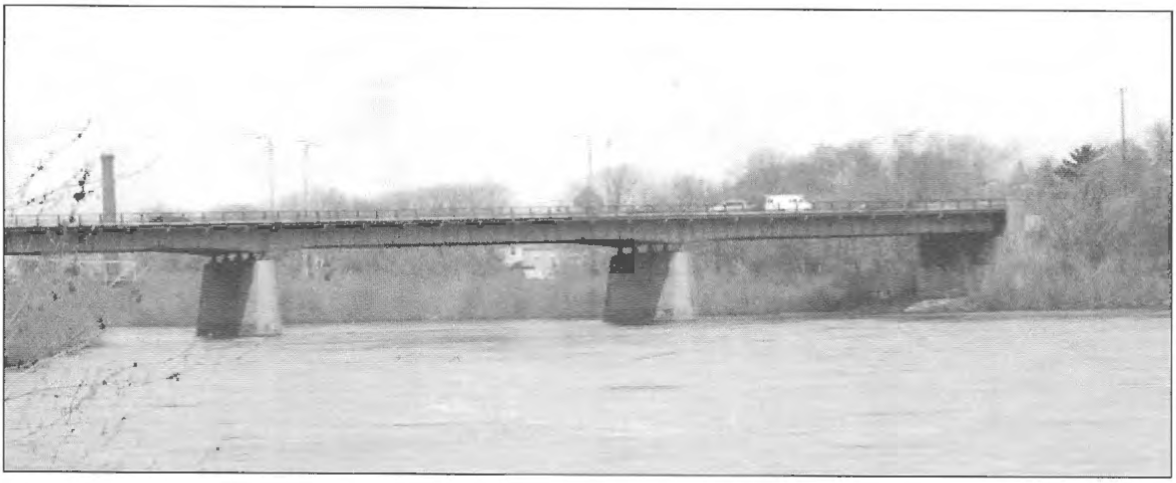
One of the most famous lenticular bridges, Gustav Lindenthal's (1850-1895) Smithfield Street Bridge (1883) at Pittsburgh, was based on the German "Pauli" truss, and is the only known example of the lenticular type *not* built by the Berlin Iron Bridge Company. The Aiken Street Bridge and the Smithfield Street Bridge, both erected in 1883, are among the oldest surviving lenticular truss bridges in the United States. The Aiken Street Bridge has the distinction of being the longest of this type and the only example having more than three spans. In 1954, the Aiken Street Bridge was named in memory of Joseph R. Ouellette, a Medal of Honor recipient killed in the Korean War. The Massachusetts Highway Department rehabilitated the bridge in 1998.

Central Bridge (John E. Cox Memorial Bridge), Bridge Street, Lowell, 1937

Historically known as Bradley's Ferry, this site has been utilized as a major river crossing since the early eighteenth century. In 1825, shortly after the founding of Lowell, the Massachusetts State Legislature authorized the Proprietors of the Central Bridge to erect a toll bridge between the Merrimack Company's newly established textile mills and the growing village of Centralville. In 1826, Luke S. Rand, a Vermont contractor working on the construction of the mill complex, built the four-span wooden truss structure known as Central Bridge. After being rebuilt in 1843, covered in 1849 and rebuilt again in 1862, the bridge was destroyed by fire in 1882. Its successor, a three-span iron Whipple truss, carried traffic for over half a century, until it, too, met with disaster during the floods of 1936.

The present 474-foot steel cantilever through truss bridge was erected in 1937. It is the oldest of only a few cantilever through truss bridges in Massachusetts, one other being the Tobin Memorial Bridge (1949) in Boston. Cantilever bridges consist of a pair of anchor arms extending from the abutments to the piers, which counterbalance a pair of cantilever arms extending from the piers over the remaining void to support a simple, suspended span. This type of bridge is advantageous for long spans because of the material savings inherent to continuous structures, and because it can be built out from both ends without erecting falsework.

The cantilever design was used for rudimentary wooden plank bridges in ancient China, but was not utilized for major spans until the mid-nineteenth century, when Heinrich Gerber constructed the first modern cantilever bridge, the Hassfurt Bridge (1867), over the Main River in Germany. A decade later, in 1878, Charles Shaler Smith (1836-1886) erected the first cantilever truss bridge in the United States, across the Kentucky River at Dixville, Kentucky. In the late nineteenth century, the potential of the cantilever form was demonstrated with the construction of the immense Forth Rail Bridge (1890), after which the type became popular for railroad bridges, largely because of its rigidity under moving loads. The subsequent construction disasters involving the Quebec Bridge (1907/1914) curtailed this enthusiasm, but also prompted a period of scientific structural analysis and re-evaluation of engineering practices from which the cantilever form emerged with renewed acceptance. The type came into common use for both railroad and highway spans in the United States around the 1930s, when many trusses of this type were erected, including spans of the Carquinez Strait Bridge (1927), Pulaski Skyway (1932) and Oakland Bay Bridge (1936). Under Chapter 586 of the Acts of 1985, Central Bridge was renamed in memory of former Lowell City Councillor John E. Cox.



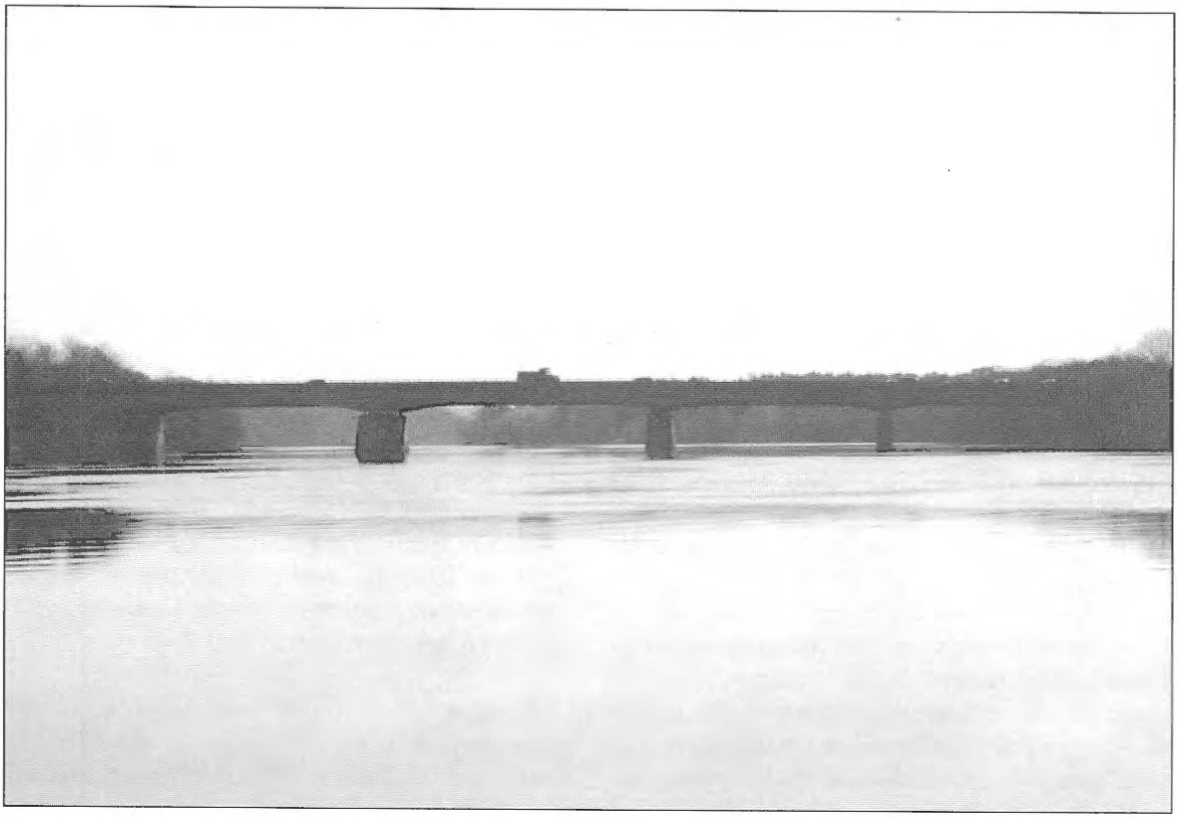
Hunts Falls Bridge (Quinn-Holmes Bridge), Route 38, Lowell, 1952

The Hunts Falls Bridge was designed and constructed by the Massachusetts Department of Public Works in 1952 when Route 38 was developed as part of the state highway system. Prior to that date, the nearest crossing of the Merrimack was at Central Bridge, access to which required driving through the congestion of downtown Lowell. The 450-foot long structure consists of three continuous spans of variable-depth, riveted steel girders.

Girder bridges are the simplest type of bridge, based on the ancient principle of the trabeated structural system (*i.e.*, a horizontal beam supported at both ends). Primitive types of girder bridges, such as a tree trunk or stone slab laid across a stream, have been used since the beginning of time, but metal girder bridges were unknown until the nineteenth century. Beginning in 1784 in England, wrought iron beams and rails were produced by rolling, but for many decades the cross-sectional size of beams that could be produced by this process was modest and not adequate for bridge-building. The earliest prototypes for metal girder bridges were built in the 1840s, using the same techniques employed in the construction of locomotives and steam boilers.

In 1845, Robert Stephenson (1803-1859) and William Fairborn (1789-1874) designed a unique, wrought iron box girder for the Britannia Bridge (1850), and at nearly the same time, American railroad mechanic James Milholland (b. 1812) constructed the first plate girder bridge (1847) for the Baltimore & Susquehanna Railroad at Bolton Station, Maryland. These early designs developed out of the mid-nineteenth-century tradition of riveting plates and angles together to create larger structural members capable of spanning greater distances than could be produced by the rolling process alone. By the end of the nineteenth century, girders were still considered uneconomical for long spans because they required more structural material than truss bridges of comparable length, but their popularity grew as their lower fabrication, erection and maintenance costs became evident.

At the end of the nineteenth century, continuous girders, such as those used in the Hunts Falls Bridge, were developed. Continuous girders extend over more than two supports, thereby allowing loads on one span to be resisted, in part, by adjacent spans. This redistribution of stresses results in lower maximum bending moments compared with simple spans, which saves material by allowing the use of lighter girder sections, or by allowing the same size sections to extend over a greater span. The haunches supply a greater web depth over the piers, where reverse or negative bending forces occur and, in addition, introduce an aesthetically pleasing curvilinear form to an otherwise rectilinear design. Riveted girders were a popular type for railroad bridges beginning in the late nineteenth century, and became popular for highway bridges in the 1930s. Under Chapter 348 of the Acts of 1960, the Hunts Falls Bridge was renamed in honor of World War II veterans T.J. Quinn and Richard Holmes.



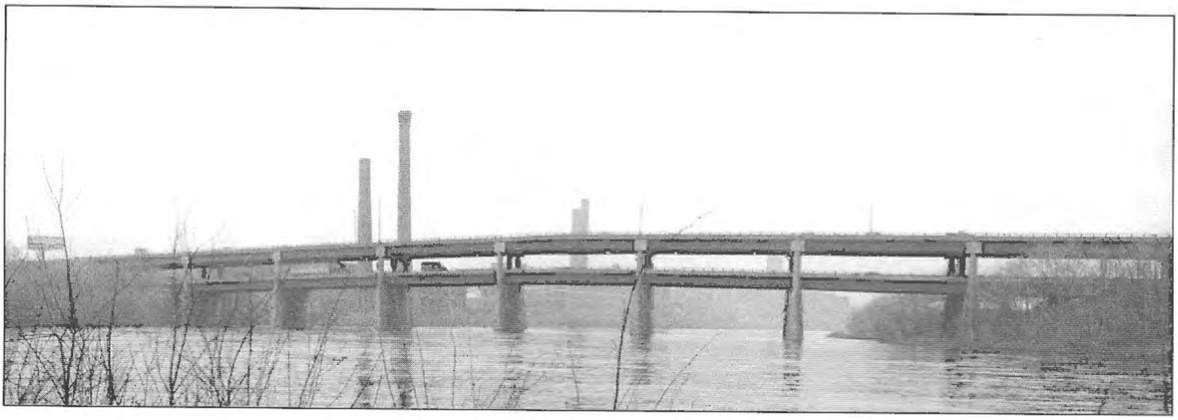
Interstate 93 Bridge (General Edward D. Sirois Bridge), I-93, Andover-Methuen, 1959/1971

This five-span, riveted steel, deck girder bridge was erected by the Massachusetts Department of Public Works in 1959 as part of the construction of Interstate 93. In 1971, the bridge was widened from four lanes to eight lanes by the addition of two lines of continuous welded girders on either side. This combination of riveted and welded construction reflects a transition in metal member fabrication that occurred slowly but steadily after World War II as the process of arc welding was refined.

In the nineteenth century, fusing two pieces of metal together by the hammering (or forge welding) method was an awkward, time-consuming process requiring the use of a forge, and was, thus, unsuited to the task of fabricating large structural members. The arc welding process, initially employed for shipbuilding, uses intense heat from a high-amperage electrical arc to create a strong metal bond quickly, thereby making fabrication of structural members more economical by reducing labor and eliminating much of the material waste associated with riveting.

Welded girders, which weigh about 15 percent less than riveted girders of the same capacity, were commonly used in buildings after World War II, but their use in bridges was delayed by a lack of information about the impact resistance of welded metal. When experiments proved that welded girders were as reliable as their riveted counterparts, welded girders became an attractive option for the hundreds of bridges required in the construction of public highways from the late 1950s on.

For mid-twentieth-century highway officials, an added attraction of welded girder bridges was their efficient, streamlined appearance — a look that was in keeping with the "modern" design aesthetic of the post-war era. Today, both riveted and welded girder bridges are commonplace, but often unnoticed features on highways across the nation. Under Chapter 784 of the Acts of 1968, the Interstate 93 Bridge was named in memory of General Edward D. Sirois, a former member of the Massachusetts General Court and vetern of three wars.



Interstate 495 Bridge (Rev. James T. O'Reilly Bridge), I-495, Lawrence, 1962

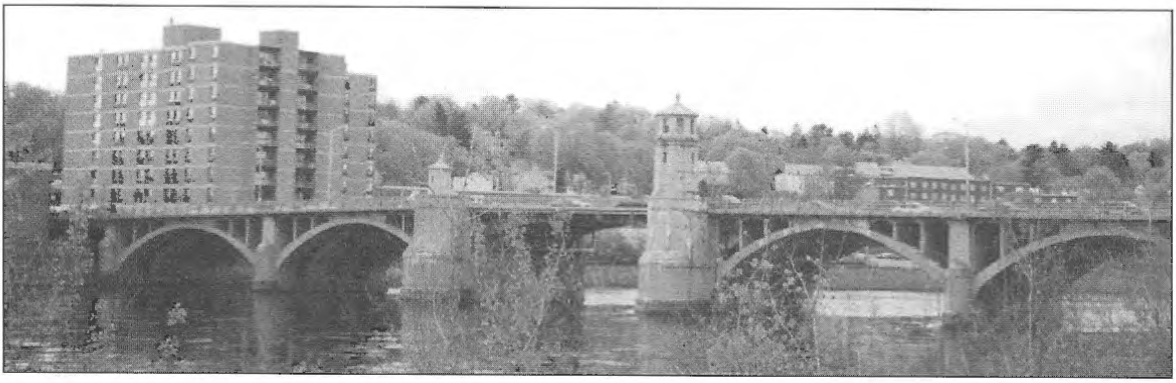
In 1944, the federal government initiated the National System of Interstate and Defense Highways to create an integrated network of 41,000 miles of highways connecting the major metropolitan regions in the United States. This program, described by President Eisenhower as, "the greatest public works program in history," was launched full-scale in 1956, when the Federal Aid Highway Act authorized 41 billion dollars in funding over a period of thirteen years for interstate highway construction. Under this program, Interstate 495 was designed as an 88-mile controlled access circumferential superhighway forming an "outer beltway" around metropolitan Boston and through the Merrimack River Valley, a region of Massachusetts seen as having potential for industrial and economic growth. At Lawrence, where a number of existing routes would converge with the interstate both north and south of the Merrimack River, highway engineers designed this 1,200-foot, eight-span, double-deck, welded steel girder bridge in accordance with federally prescribed standards, to promote safe and efficient traffic flow patterns in an area of anticipated heavy traffic congestion. The bridge was described in the *Master Plan of Highways for Lowell-Lawrence-Haverhill*, as follows:

> "The new Merrimack River Bridge will have two highway decks; the upper one for through traffic and the lower one for traffic which will utilize either one or both of the adjacent traffic interchanges for local distribution. This plan will provide needed local traffic service between North Andover and areas of northern Lawrence."

Bridges with multiple levels have been built since ancient times. For example, the Pont du Gard (ca. 14 A.D.) in southern France carried an aqueduct on one level and a roadway on another level; the Newburyport Railroad Bridge (1840-1865) had separate levels for horse-drawn carriages and steam-powered trains; and the Brooklyn Bridge (1883) has a pedestrian walkway above the deck carrying automobile traffic.

The first modern double-deck highway bridge was built on Wacker Drive in Chicago in 1925, and the design increased in popularity during the mid-twentieth century as numerous expressways were built in metropolitan areas across the United States. Today, double-deck highway bridges are frequently encountered in urban settings where there is a large volume of high-speed traffic and many interchanges occur in a confined space with limited right-of-way.

Under Chapter 379 of the Acts of 1963, the Interstate 495 Bridge was named in memory of the Reverend James T. O'Reilly, who served as pastor of Saint Mary's Catholic Church in Lawrence from 1886 to 1925, in remembrance of his public spiritedness and service to the community.



Haverhill Bridge (Lower County Bridge/Pfc. Ralph T. Basiliere Bridge), Main Street, Haverhill, 1925

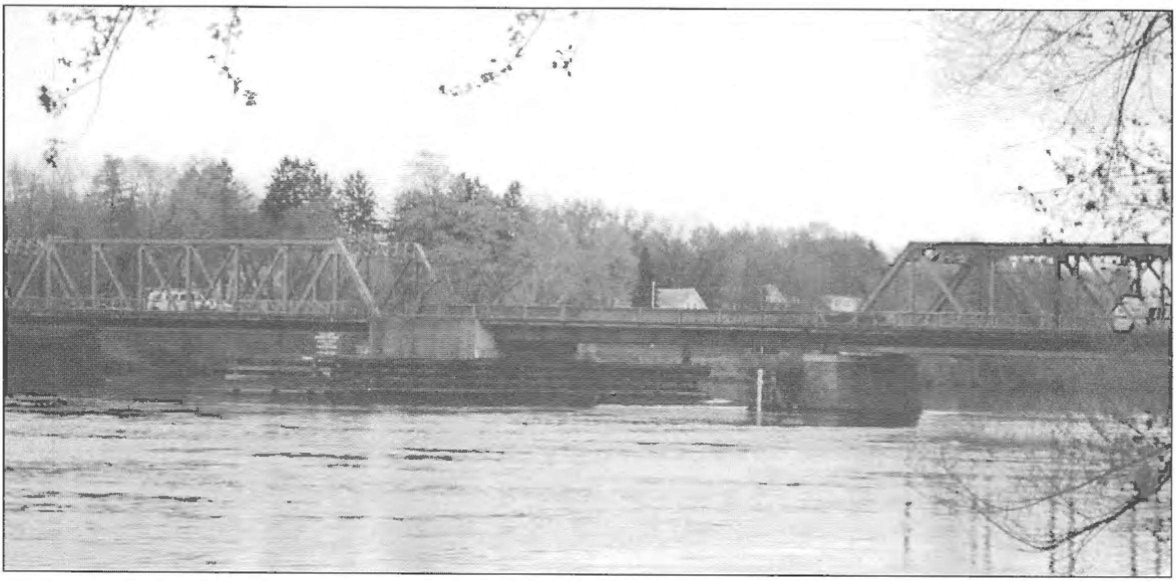
In 1793, the Proprietors of the Haverhill Bridge Company erected a wooden toll bridge at this site. The bridge was a three-span arched timber truss structure, designed by local builder Timothy Palmer, who had recently completed the first bridge across the Merrimack at Newburyport. After being rebuilt in 1808 and covered in 1825, the Haverhill Bridge carried traffic for half a century, until it was replaced with an iron Whipple truss structure in 1873.

The present six-span, open-spandrel, reinforced concrete deck arch bridge was erected to replace the iron bridge in 1925. This bridge was designed by George F. Swain (1857-1932), a civil engineer of national renown who consulted on the construction of a number of important Massachusetts bridges (including several on the Merrimack). The Strauss Bascule Bridge Company designed the bridge's trunnion bascule draw span, but the operating machinery was never installed, as plans to make the Merrimack navigable to Lowell were never implemented.

The Haverhill Bridge is one of two reinforced concrete open-spandrel arch bridges on the Merrimack, the other being the Central Bridge (1918) at Lawrence. (A third reinforced concrete open-spandrel arch bridge spanned the Merrimack at Pawtucket Falls in Lowell from 1916 to 1968.) Although similar in design, the Haverhill Bridge is more aesthetically successful in that its bascule span was an integral part of the overall design, while the proportions of the Central Bridge were compromised when it was redesigned during construction to accommodate a proposed bascule span that was later eliminated from the design.

According to the MassHighway Historic Bridge Inventory, the Haverhill Bridge is one of only six open-spandrel rib arch bridges in the state, and it is noteworthy for its unusually ornate neo-classical details. The practice of combining the compressive strength of concrete with the tensile strength of metal reinforcing began the 1860s with experiments by French gardener Joseph Monier (1823-1906), who used iron netting to reinforce flower pots and planters. In the 1870s and 1880s, others extended these experiments to larger structures such as beams, slabs and arches. The first reinforced concrete arch bridge in the United States, the Alvord Lake Bridge in Golden Gate Park, was built in 1889 by Ernest Ransome (1844-1917), who patented the twisted-bar reinforcing system that became the basis for most common systems in use today. Ransome's structure emulated the traditional design of masonry bridges through its use of the solid-barrel arch form and surface treatments that purposely imitated the appearance of stone.

As engineers gained experience with the structural properties of reinforced concrete in the early twentieth century, they sought to use the material more efficiently. By relying on the tensile strength of the reinforcing steel, instead of the compressive strength of a ponderous mass of concrete alone, they were able to attenuate the arch ribs and open up the spandrel walls, thereby creating increasingly lighter structures of more elegant proportions. Under Chapter 231 of the Acts of 1972, the Haverhill Bridge was renamed in honor of U.S. Marine Pfc. Ralph T. Basiliere, Haverhill's first casualty of the Vietnam War.



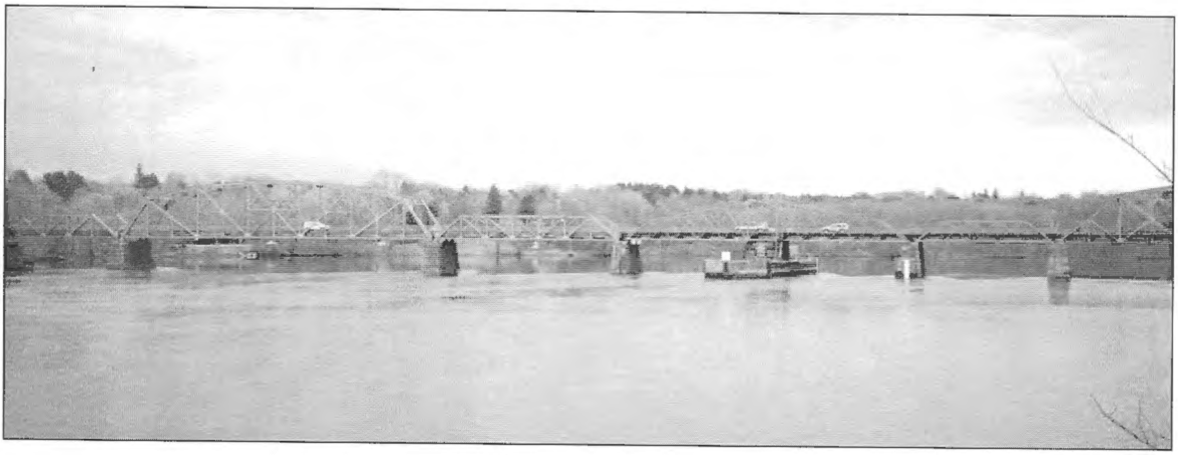
Groveland Bridge (Congressman William H. Bates Bridge), Groveland Street-Main Street, Haverhill-Groveland, 1913/1950

A chain ferry operated at this location for nearly 140 years until the first bridge was built here in 1872. It was a five-span, wrought iron, tubular arch bridge, patented by Zenas King (1818-1892) in 1861. Proclaimed "a perfect model of symmetry and beauty," this bridge carried traffic for ten years until it collapsed under the weight of snow and an overloaded lumber wagon. The damaged structure was replaced in 1882 with an iron structure consisting of five Warren through truss spans and a central swing span.

In 1913, the southern spans of the bridge were consumed in a fire caused by faulty street railway wiring. The three burned trusses were replaced with the present three 123-foot, riveted Pratt through truss spans at the southerly end of the bridge, and the structure was put back in service the following year. In 1950, the bridge's two northerly spans were replaced with two 140-foot, riveted Pratt through trusses (of slightly heavier construction than the southern spans), and the draw was replaced with the present bascule girder span.

A bascule is one of the three major types of movable bridges, along with swing and lift spans. The term *bascule* comes from the French word meaning *see-saw* since the principle of counter-balance is fundamental to its design. A bascule bridge has one or two counterbalanced leaves that pivot about a horizontal axis at one end and lift at the other end to provide a clear passage for boats. Unlike swing bridges, which pivot on a central pier, and lift bridges, which are raised and lowered horizontally between vertical towers, bascule bridges can be rapidly opened and closed, allow unlimited vertical clearance in the open position and do not restrict the navigation channel. The bascule concept was originally used in medieval times for drawbridges over castle moats and, in the sixteenth century, Leonardo da Vinci (1452-1519) made sketches of a rudimentary bascule bridge with a counterweight. However, the modern bascule bridge was not fully developed until 1890 when an efficient method of counterbalancing the weight of the span had been found and electric motor technology refined.

The first modern bascule bridges were the Van Buren Street Bridge (1893) in Chicago and the Tower Bridge (1894) in London. Bascule bridges are now the most common type of movable highway bridge found in Massachusetts. Twenty-nine examples of this type have been identified among the 44 movable bridges listed in the MassHighway statewide bridge database. The Groveland Bridge contains one of two operable bascule spans on the Lower Merrimack. Under Chapter 621 of the Acts of 1970, the Groveland Bridge was named in memory of William H. Bates, a local congressional representative.



Merrimac Bridge (Rocks Bridge), Haverhill-West Newbury, 1883/1895/1914

In 1794, the Massachusetts General Court authorized the Proprietors of the Merrimac Bridge to construct a toll bridge at Rocks Village in Haverhill. Completed in 1795, it was the fifth bridge to span the Merrimack River, replacing a ferry system that had been in operation since the late seventeenth century. The bridge had pile and beam approaches, a 30-foot draw and a 140-foot arched timber truss, based on Timothy Palmer's design.

The bridge was washed away in a freshet in 1818, and rebuilt on the old foundations ten years later as a 900-foot, four-span covered wooden Town lattice truss (patented in 1820 by Connecticut architect Ithiel Town [1784-1844]) with a central drawspan, which held the record as the longest covered bridge in New England for many years. With the passage of time, sections of the bridge were replaced with new spans of various types and sizes, resulting in the somewhat irregular appearance of the present bridge. The draw was replaced in 1873 and again in 1883, when the present iron swing span and adjacent pony truss span were erected. In 1895, the wooden span at the Haverhill end was replaced with a Pennsylvania through truss designed by Edward S. Shaw.

The bridge reached its present 812-foot, six-span configuration in 1914, when the Essex County Commissioners replaced the remaining wooden spans east of the draw. Initial plans to replace the wooden trusses with reinforced concrete arches were eventually discarded in favor of the present three steel Pratt trusses designed by George F. Swain (1857-1932). The trusses were adopted as a cost-saving measure in order to utilize some of the old piers and resulted in spans of unequal length and different design, which fortunately provided visual balance to the truss configuration at the Haverhill end, and were, thus, in the County Engineer's estimation "not as objectionable as might be expected."

Of the bridge's six spans, the rim-bearing swing span is the most technologically significant since it is the oldest movable highway span in Massachusetts. Swing bridges, which rotate about a vertical axis, were first built in the United States in the early nineteenth century across the Erie Canal and eventually became the dominant type of movable bridge by the end of the century. The Rock Island Bridge (1896) across the Mississippi and the Center Street Bridge (1901) at Cleveland are two famous examples.

The Rocks Bridge is one of two operable swing bridges on the Merrimack, the other being the Deer Island Drawbridge. Comparison of the two operable swing spans reflects the changes in swing bridge construction that occurred around the turn of the century: from rim-bearing to center-bearing systems; from through truss to deck plate girder superstructure; and, from manual to electrical operation. According to the MassHighway Historic Bridge Inventory, the Rocks Bridge swing span is one of the oldest riveted metal trusses in the state and the earliest surviving work of the Boston Bridge Works, one of the largest independent bridge manufacturers in New England from the 1870s through the 1930s whose work is well-represented on the Lower Merrimack.

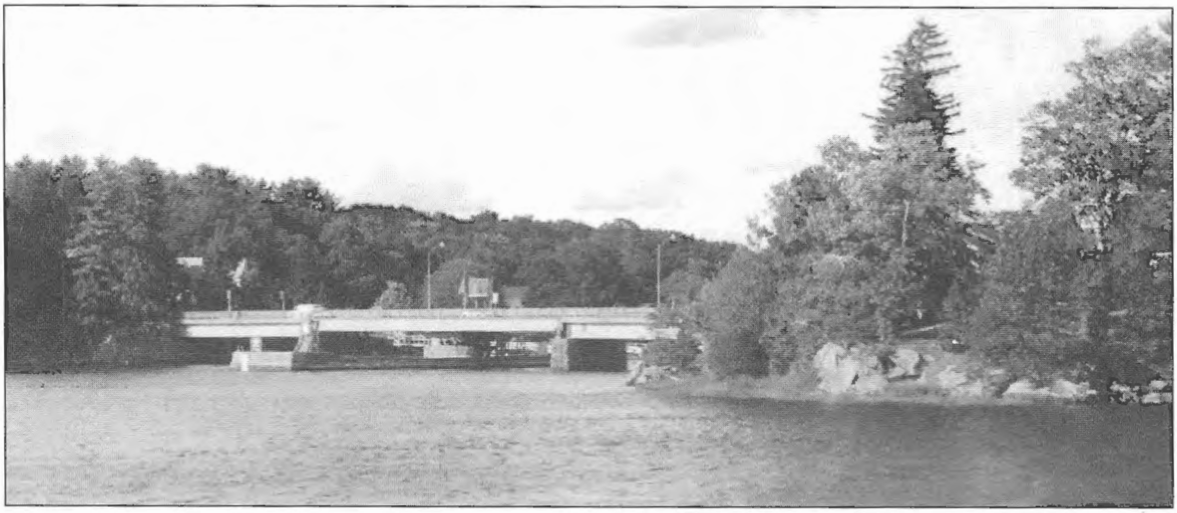
John Greenleaf Whittier Bridge, I-95, Amesbury-Newburyport, 1952

This 1,346-foot, three-span, riveted steel, continuous through truss bridge was completed in 1952 as part of the construction of Interstate 95, a limited-access route that parallels Route 1 from Maine to Florida. The bridge was designed by Massachusetts Department of Public Works engineers. Although the main span of this bridge forms an arch over the navigation channel, the bridge's structural action is that of a continuous truss rather than an arch. The continuous truss acts as a unit over more than two supports. Therefore, stresses from live loads are transferred to members in adjacent spans. The advantages of a continuous bridge over a simple span bridge are economy of material, convenience of erection and increased rigidity under traffic.

Continuous bridges were built in England as early as the 1850s, and in the United States in the 1870s, but because continuous bridges are subject to secondary stresses from pier settlement, this type of structure was initially used only for short spans. After the beginning of the twentieth century, longer spans of this type were gradually introduced, first for railroads in the 1910s, and then for highways in the 1920s. The first major bridge of this type in the United States was Gustav Lindenthal's 775-foot Sciotoville Bridge (1917) spanning the Ohio River at Fullerton, Kentucky.

The continuous through truss type came into common use in the 1930s, when monumental spans were erected, including the Bourne (1934) and Sagamore (1935) bridges over the Cape Cod Canal. These nearly identical bridges each received a design award from the American Institute of Steel Construction.

According to the MassHighway Historic Bridge Inventory, the John Greenleaf Whittier Bridge is essentially a half-scale, double-barrel version of the Bourne and Sagamore bridges, but is somewhat less successful aesthetically due to the elongated approach spans. Under Chapter 460 of the Acts of 1953, the bridge was named in honor of distinguished Haverhill native John Greenleaf Whittier (1807-1892), whose essays and poetry include many references to the Merrimack River and its bridges.



Essex-Merrimac Bridge, Northern Span (Deer Island Drawbridge), Main Street, Amesbury, 1966

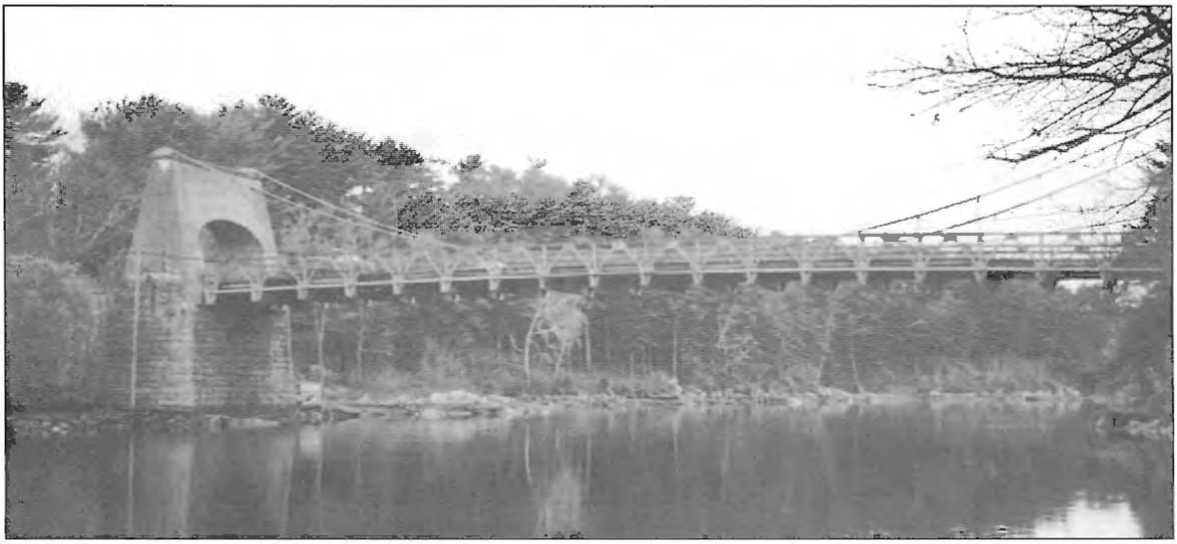
At Deer Island, the Merrimack is spanned by separate bridges over the north and south river channels: a swing bridge connecting the island to Amesbury on the north side of the river; and a suspension bridge connecting the island to Newburyport on the south side of the river. This place was the site of the first bridge across the Lower Merrimack, erected in 1792 by Timothy Palmer (1751-1821), a builder from Newburyport. The bridge approaches were simple pile and beam structures with a draw over the northern channel, while the main spans (measuring 113 feet and 160 feet) were arched timber trusses, which resembled (or may have been directly adapted from) the sixteenth-century designs of the Italian architect Andrea Palladio (1518-1580), who was the first to illustrate and build a truss bridge.

The timber truss covered bridge was developed in Europe by Swiss carpenter Hans Ulrich Grubenmann (1709-1783), whose most famous span was the arched timber Schaffhausen Bridge (1757) across the Rhine, but wooden bridges were not commonly built until the end of the eighteenth century, when the idea found its way to America. Several contemporary references suggest that a 1764 "geometry work" bridge at Norwich, Connecticut, may have been the first use of the truss principle in American bridge design, but Palmer's Essex-Merrimac Bridge is generally considered the first long-span timber truss bridge in the United States.

Palmer's most famous bridge, the Permanent Bridge (1806) over the Schuylkill River in Philadelphia, was his longest (194 feet) arched timber truss span to that date and one of the first covered bridges in America. The preservation measure of roofing and weatherboarding wooden trusses was so effective that it soon became conventional practice, and was applied to all wooden bridges on the Merrimack by the 1820s.

Palmer's successors, Louis Wernwag (1769-1843) and Theodore Burr (1771-1822), continued to use empirically-designed arch-truss combinations for timber bridges, until they were eventually superceded in the 1820s and 1830s with designs of Ithiel Town (1784-1844) and Stephen Long (1784-1864), which dispensed with the arch form entirely, and thus heralded the many scientifically designed truss forms to follow.

After being covered around 1810, and possibly rebuilt in the mid-nineteenth century, the northern timber span of Palmer's Essex-Merrimac Bridge lasted until 1882, when it was replaced with an iron, three-span, double-intersection Warren through truss with a rim-bearing swing span. When that bridge was destroyed by fire in 1965, the present rolled steel girder, center-bearing swing span was erected in its place. The operating machinery was motorized in 1971. The Deer Island site is historically significant for its association with Palmer's pioneering work in timber truss bridge design.



Essex-Merrimac Bridge, Southern Span (Chain Bridge), Main Street, Amesbury-Newburyport, 1909

At the time of its construction, the Essex-Merrimac Bridge was considered a great engineering achievement, but was denounced by boatmen as a hindrance to navigation. Thus, in 1810, the timber truss spanning the southern channel was replaced with a then-novel type of structure to allow easier passage for boats. Designed by Judge James Finley (1756-1828) of Pennsylvania, the bridge featured a deck suspended from wrought iron chains that hung between wooden towers spaced 243 feet apart.

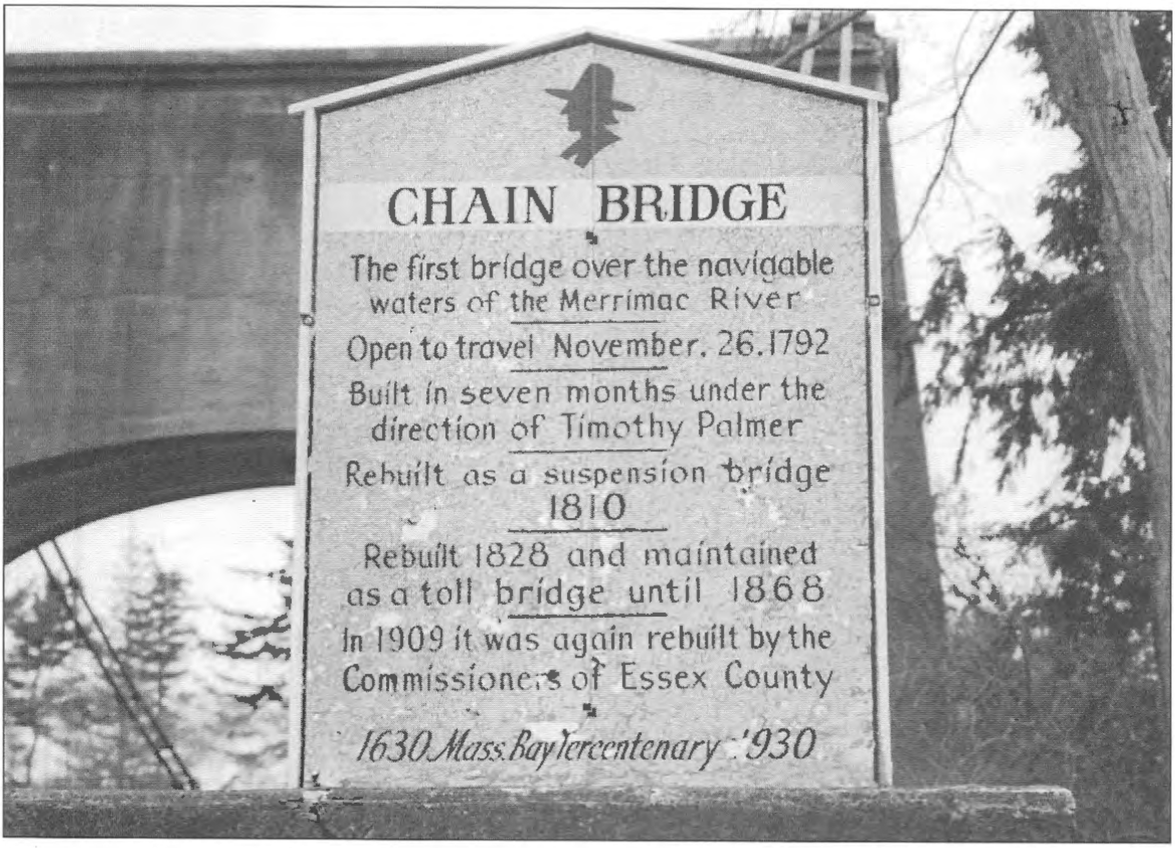
Unlike primitive suspension bridges, which deflected significantly under loads, Finley's bridge combined a catenary suspension cable of wrought iron links with a stiffening truss for the roadway, to create a suspension bridge with a rigid, level deck. In 1801, he built the first suspension bridge in America, a 70-foot span, at Uniontown, Pennsylvania, and in 1808 he was granted a patent for his design. About 40 bridges were built based on this patent. Finley's longest span was a 308-foot pedestrian bridge (1809) in Philadelphia, but he confidently asserted that much longer spans were possible, and thus foreshadowed the work of his successors:

> "There is no reasonable doubt that in some extraordinary case this kind of bridge will be extended to one thousand feet once the subject shall be fully understood . . . Let us pursue the idea of extension to 15,000 feet without any middle pier."

Descriptions of Finley's work were published in the United States and abroad, and may have influenced the design of other iron chain suspension bridges built in the next two decades, including Capt. Samuel Brown's (1776-1852) Union Bridge (1820) between England and Scotland, a five-span iron chain suspension bridge across the Merrimack at Newburyport (1826) and Thomas Telford's (1757-1834) Menai Strait Bridge in Wales (1826). The major drawback of the design was that the chains were vulnerable to manufacturing flaws and corrosion: if one link failed, the whole bridge could collapse. This problem was illustrated when the Essex-Merrimac Chain Bridge failed under a heavy load in 1827.

Although the bridge was rebuilt following Finley's original design and continued to carry traffic for 80 years, wrought iron chain bridges were losing popularity. During that period, wire cable technology — which promised greater reliability and roughly two times the tensile strength of forged bars for a given sectional area (and thus the possibility of truly long spans) — began replacing wrought iron chain designs in France and the United States.

In 1841, Colonel Charles Ellet (1810-1862) erected the first successful wire cable suspen-



Commemoration plaque on the Chain Bridge.

sion bridge across the Schuylkill in Philadelphia, and just eight years later, he built a record-breaking 1,010-foot wire cable span at Wheeling, West Virginia. Simultaneously, another pioneer in the field, John A. Roebling (1806-1869), was working on suspension aqueducts for canals. In the 1840s, he established his own wire mill and became a proponent of wire cable suspension spans. In a letter concerning the proposed suspension railroad bridge at Niagara Falls (1855) he stated:

> "It cannot be questioned that wire cables, when well made, offer the safest and most economical means for the support of heavy weights . . . There is not one good suspension bridge in Great Britain, nor will they ever succeed as long as they remain attached to their chains."

With Roebling's vision and the steady development of wire cable technology, suspension bridges grew increasingly longer. At the end of the century, Roebling's monumental, 1,595-foot Brooklyn Bridge (1883) held the world record for suspension bridge spans. While diminutive in comparison to the Brooklyn Bridge, the Chain Bridge had became a cherished historic and visual landmark by 1909, when it was turned over to the county for rebuilding. In deference to local sentiment that wanted to retain the appearance of the 80-year old structure, consulting engineer George F. Swain (1857-1932) designed the present bridge to echo the form and massing of the former structure, but utilized state-of-the-art materials, including reinforced concrete towers and steel wire cables, for strength and durability.

Although rebuilt in essentially modern form, the Chain Bridge is historically significant for its association with Finley's pioneering suspension bridge that formerly spanned this location, and is structurally significant as the only highway suspension bridge in Massachusetts. The Massachusetts Highway Department is currently developing plans to rehabilitate this picturesque historic landmark.

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