New Hampshire DOT
Department of Transportation

THE STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION

Victoria F. Sheehan
Commissioner

William Cass, P.E.
Assistant Commissioner

January 12, 2016

John Bohenko, City Manager
City of Portsmouth
1 Junkins Avenue
Portsmouth, NH 03801

Portsmouth Historical Society
10 Middle Street
Portsmouth, NH 03801

Portsmouth Athenaeum
9 Market Square
Portsmouth, NH 03801

Re: Portsmouth, X-A000(417), 14493 – Replacement of the Sagamore Creek Bridge
Section 106 Historic Mitigation Stipulation, Historic Property Documentation

To Whom It May Concern,

The New Hampshire Department of Transportation is providing you a copy of the New Hampshire Historic Property Documentation that was completed for the Portsmouth 14493 project that replaced the Sagamore Creek Bridge. As part of the Section 106 historic mitigation for the removal of the bridge, the City committed to completing archival documentation, please see the enclose Memorandum of Agreement for the documentation specifics.

Please add the enclosed to your collection, and do not hesitate to contact me with any questions.

Thank you,

Jill Edelmann
Cultural Resources Manager
Bureau of Environment
603-271-7968
jedelmann@dot.state.nh.us

cc. Dave McNamara, FST
Jamie Sikora, FHWA
Laura Black, NHDHR

Portsmouth – State Project No. #14493
Federal Project No. X-A000(417)

MEMORANDUM OF AGREEMENT
SUBMITTED TO THE ADVISORY COUNCIL ON HISTORIC PRESERVATION
PURSUANT TO 36 CFR 800.6 (c)
PROPOSED REPLACEMENT OF THE SAGAMORE CREEK BRIDGE
PORTSMOUTH, NEW HAMPSHIRE

WHEREAS, The City of Portsmouth, with funding from the New Hampshire Department of Transportation (NHDOT) and Federal Highway Administration (FHWA), proposes to replace the Sagamore Avenue Bridge over the Sagamore Creek (the undertaking); and

WHEREAS, FHWA has determined that the proposed undertaking will have an adverse effect upon the existing Sagamore Creek Bridge, a property eligible for listing on the National Register of Historic Places (NR), and has consulted with the New Hampshire State Historic Preservation Officer (NHSHPO) pursuant to 36 CFR Part 800, regulations implementing Section 106 of the National Historic Preservation Act of 1966, as amended [16 U.S.C. Part 470(f)]; and

WHEREAS, the NHDOT has participated in the consultation and has been invited to participate in the Memorandum of Agreement (MOA); and

WHEREAS, the City of Portsmouth has participated in the consultation process, has solicited public comment through the public meetings and the consulting party procedures with FHWA as stated in 36 CFR 800 (2), and is invited to participate in this Memorandum of Agreement (MOA); and

WHEREAS, in accordance with 36 CFR 800, the FHWA acknowledges and accepts the advice and conditions outlined in the Advisory Council on Historic Preservation's "Recommended Approach for Consultation on the Recovery of Significant Information from Archaeological Sites," and other mitigation procedures published in the Federal Register on May 18, 1999; and

Whereas, in accordance with 36 CFR 800, the FHWA has notified the ACHP of its adverse effect determination with specified documentation and the ACHP has chosen not to participate in the consultation pursuant to 36 CFR 800.6(a)(1)(iii).;

NOW, THEREFORE, FHWA, NHSHPO, NHDOT and the City of Portsmouth, agree that the undertaking will be implemented in accordance with the following stipulations in order to take into account the effect of the undertaking on historic properties.

STIPULATIONS

The FHWA will ensure that the following mitigation measures are carried out in consultation with the parties to the agreement.

A. PREPARATION OF A NH HISTORIC PROPERTY DOCUMENTATION FORM

The City of Portsmouth will retain the services of a 36 CFR 61 qualified architectural historian to prepare a NH Historic Property Documentation Form (NHHPDF). The report will include a cover sheet; detailed description of the bridge; a narrative; archival quality copies of extant design plans; large format negatives and contact prints of the bridge; location map; and photographic description and key. The narrative will include the historical background of the crossing; a discussion of the planning and construction of the bridge incorporating the effects of World War

II on its construction; information on the bridge designer, fabricator, and construction contractor; a discussion of the development of the plate girder bridge type and this subtype; a comparative analysis with other deck plate girders, specifically with Littleton 109/134, Conway 170/071, Lebanon 077/107, and Stratford 029/206; and a summary statement of significance. The NHHPDF will also include a summary structural analysis of the bridge and stress distribution to key bridge components.

The large format photos, sketch map showing the direction of photos with a detailed photo key, and the detailed description of the bridge and the abutments will be submitted to the NHDOT and NH SHPO at least 12 weeks prior to the planned demolition of the bridge to allow a 45 day review period by those agencies. Any comments or corrections noted must be incorporated into the photos, map, or detailed descriptions. Those documents shall then be resubmitted to NHDOT and NHSHPO at least 45 days prior to the demolition of the bridge for a final review. The remainder of the report shall be finalized within 1 year of project completion. Five copies of the report, three of which will be produced as archival-quality documents, will be distributed to NHSHPO, FHWA, NHDOT, the Portsmouth Historical Society, the Portsmouth Athenaeum, and the City of Portsmouth.

B. MARKETING OF THE BRIDGE

The bridge will be marketed as required by 23 USC 144. The bridge will be advertised once with covenants in a local and regional newspaper, leaving one month for response. Federal-Aid Highway Funds will be made available for the relocation of the bridge up to the estimated cost of demolition. The City of Portsmouth will be responsible for the marketing of the bridge.

C. Prioritization of NHDOT Statewide Bridge Inventory and Management Plan

It is understood that the NHDOT will incorporate this plate girder bridge type into the future Statewide Bridge Inventory and Management Plan as a priority. The Statewide Bridge Inventory and Management Plan commitment was part of a previous memorandum of agreement for the Lebanon-Hartford Project # 14957.

D. ARCHAEOLOGICAL CONSIDERATIONS

1. If changes during final design cross archaeologically sensitive property, then all necessary phases of archaeological investigations will be completed.

2. If human remains and grave-associated artifacts are discovered while carrying out the activities pursuant to this MOA, the FHWA, the City of Portsmouth, and NHDOT will immediately notify the appropriate authorities, as prescribed by New Hampshire statutes to determine an appropriate course of action in accordance with the Advisory Council on Historic Preservation's (Council's) Revised "Policy Statement Regarding Treatment of Burial Sites, Human Remains, and Funerary Objects," adopted by the Council on February 23, 2007 at its quarterly business meeting in Washington, D.C.

FHWA will ensure that the following items and conditions are implemented.

I. DISPUTE RESOLUTION

Should any signatory to this Memorandum object within thirty (30) days to any actions proposed or carried out pursuant to this agreement, the FHWA shall consult with all parties to resolve the objection. If the FHWA determines that the objection cannot be resolved, the FHWA shall forward all documentation relevant to the dispute to the Advisory Council on Historic Preservation (Council). Within thirty (30) days after receipt of all pertinent documentation, the Council will either:

a. Provide the FHWA with recommendations which they will take into account in reaching a final decision regarding the dispute; or

b. notify the FHWA that it will comment pursuant to 36 CFR 800.6(b), and proceed to comment. Any recommendations or comment provided by the Council will be understood to pertain to only the subject of the dispute; the FHWA responsibility to carry out all actions under the Memorandum of Agreement that are not subjects of the dispute will remain unchanged.

At any time during the implementation of the measures stipulated in this agreement should any objection regarding the subject matter of this agreement be raised by a member of the public, the FHWA shall take the objection into account and consult as needed with the objecting party, and all other parties to the agreement, or the Council to resolve the objection.

II. TERMINATION

If any signatory determines that the terms of the MOA cannot be executed, the signatories shall consult to seek amendment of the agreement. If the agreement is not amended, any signatory may terminate the agreement. If the terms of this agreement have not been implemented by December 9, 2017, this agreement shall be considered null and void. In any such event, the agency shall notify the parties to this agreement, and if it chooses to continue with the undertakings, shall reinitiate review of the undertaking in accordance with 36 CFR 800.

III. AMENDMENT

This Memorandum may be amended when such an amendment is agreed to in writing by all signatories. The amendment will be effective on the date a copy signed by all of the signatories is filed with them. Execution of the Memorandum of Agreement by the FHWA, NHSHPO, the City of Portsmouth, and the NHDOT, its subsequent filing with the Council, and the implementation of its terms, shall establish that the FHWA has taken into account the effects of the undertaking on historic properties.

Portsmouth – State Project No. #14493
Federal Project No. X-A000(417)

Federal Highway Administration

By:____________________ Date: 09/14/2012
for Patrick A. Bauer
FHWA Administrator

NEW HAMPSHIRE STATE HISTORIC PRESERVATION OFFICER

By:____________________ Date: 9/12/12
Elizabeth H. Muzzey
State Historic Preservation Officer
Director of the Division of Historical Resources

CITY OF PORTSMOUTH

By:____________________ Date: 9-7-12
John P. Bohenko
City Manager, City of Portsmouth

New Hampshire Department of Transportation

By:____________________ Date: 9/13/12
William Cass
Director of Project Development

NEW HAMPSHIRE HISTORICAL PROPERTY DOCUMENTATION
SAGAMORE CREEK BRIDGE PORTSMOUTH, NH

NH STATE NO. 713

Location:	Route 1A/Sagamore Avenue at Sagamore Creek, Portsmouth, New Hampshire
Date of Construction:	1941
Engineer:	John H. Wells and Harold Langley, State of New Hampshire Highway Department
Present Owner:	New Hampshire Department of Transportation 7 Hazen Drive, Concord, New Hampshire
Present Use:	Bridge
Significance:	Sagamore Creek Bridge is an excellent and well-preserved example of a continuous variable-depth riveted plate girder deck highway bridge. It is the second oldest of only four of the type surviving in New Hampshire. It is a relatively early example of its type, built during the short rapid development years of continuous plate girder bridges which began about 1930 and culminated in the 1940s. It incorporates design improvements over the earlier surviving examples that were then improved upon again in the later examples, making it a benchmark in the evolution of the type. It was designed by John H. Wells, an engineer important to the engineering history of bridges in New Hampshire. The bridge appears in the 1943 edition of *Movable and Long Span Steel Bridges*.
Project Information:	This documentation was prepared by Preservation Company, 5 Hobbs Road, Kensington, New Hampshire, for the New Hampshire Department of Transportation (NHDOT). It accompanies large format photographs of the bridge taken by Charley Freiberg, Elkins, New Hampshire, in 2013. The text is based on a New Hampshire Division of Historical Resources (NHDHR) Inventory Form for the bridge (POR0122) prepared by Preservation Company in 2010. In keeping with the terms of a Memorandum of Agreement, the text has been augmented by additional descriptive information, a discussion of the development of the plate girder bridge type and this subtype, a comparative analysis with other deck plate girders, of the bridge and a summary statement of significance (all written by Rich Casella of Historic Documentation Company, Inc.). Also in accordance with the Memorandum of Agreement, a summary structural analysis of the bridge and stress distribution to key bridge components was prepared by Thomas Densford, of Fay, Spofford & Thorndike. Additional information concerning the effects of World War II on the bridge has also been added.

PART I. HISTORICAL INFORMATION

The Sagamore Creek Bridge is located south of downtown Portsmouth roughly a half mile north of the Portsmouth/Rye town line and roughly a mile in from the seacoast. The bridge carries Route 1-A (Sagamore Avenue) across tidally-influenced Sagamore Creek. Sagamore Creek, an inlet from the Piscataqua River, has its mouth is at Portsmouth Harbor west of Little Harbor. It runs inland (west) from the coast about three miles. New Hampshire Route 1-A is part of New Hampshire's coastal highway which runs along the state's 18.32-mile coastline from the Massachusetts state line in Seabrook to Portsmouth (where it joins Route 1). For much of its length, it runs close to the ocean and is known as Ocean Boulevard. At Odiorne Point (site of Fort Dearborn) the road cuts west away from the shore around Little Harbor. It meets up with Sagamore Road at Foyes Corner and then heads north crossing into Portsmouth and becoming Sagamore Avenue. Just prior to crossing Sagamore Creek, Route 1B separates off from 1A, and heads east. (Route 1B/Wentworth Avenue/Portsmouth Avenue/New Castle Avenue is a loop which provides access to New Castle Island – and during WWII Fort Stark, Camp Langdon and Fort Constitution – and which then heads back to the west to enter Portsmouth via New Castle Avenue.) Route 1A crosses Sagamore Creek at the Sagamore Creek Bridge, continues northwest into downtown Portsmouth and eventually ends at its intersection with Middle Street (U.S. Route 1). Route 1-A is a state-designated Scenic and Cultural Byway.

History of the Crossing, Original and Early Sagamore Bridges

The Sagamore Avenue crossing of Sagamore Creek dates to 1850. This first bridge was built some fifty years after the General Assembly was petitioned to build a bridge which would "shorten the travel and facilitate the communications between [Portsmouth and Rye] . . . and be of public utility" (Hammond 1884:304). In 1850 Portsmouth and Rye cooperated on a through route between the two towns which crossed Sagamore Creek at the current bridge site. The route fostered the incipient tourist trade, including summer hotels along the coast, and in general, furthered commerce between Rye and Portsmouth.[1] The desirability of the new route was discussed in the *Portsmouth Journal* which noted that it "...will be one of the most romantic, delightful and pleasant routes, in hot weather, to the seaboard, the beaches, etc. and the distance out and in is lessened three miles. The increased facility of getting to our market all the good things from the whole length of the south shore is no mean item" (*Portsmouth Journal* 8/3/1850).

Work on the original bridge at Sagamore Creek began in the spring or early summer of 1850. It was built by Charles Trefethen of Rye for $775 (*Portsmouth Journal* 5/13/1922). By September 1850 the bridge was largely complete, but the road between the two towns was held up due to a controversy about the exact location of the boundary line between Rye and Portsmouth. The two towns eventually reached an agreement and the road in "the disputed territory" was put out to bid. The advertisement to bidders noted that "the road is to be fenced or walled, and graded, according to specifications" (*Portsmouth Journal* 9/21/1850).

[1] Portsmouth's first Mayor, Abner Greenleaf in whose term the bridge was built, may have had a role in promoting the bridge, as his residence was located near the site of the bridge (*Portsmouth Herald* 1/10/1934:8).

From 1850 onward, the wood bridge at this location was likely rebuilt numerous times over its history. For instance, the bridge was extensively "renovated" in 1884 (*Portsmouth Herald* 6/10/1954).

Around the turn of the century, two transportation improvements brought increased traffic to the area and to the bridge. In the fall of 1899, the Portsmouth Electric Railway extended a line from downtown Portsmouth along Sagamore Avenue and across the bridge to Foye's Corner then on to Rye and the beaches. Around the same time, construction began on Ocean Boulevard, the first significant New Hampshire highway project and the first state-owned highway.[2] By 1907, the Ocean Boulevard was completed by the State and its stretch of fifteen miles of unobstructed views of the Atlantic Ocean quickly became a new destination for the burgeoning automobile-driving public.

With the increased traffic, the old pile and timber Sagamore Bridge was increasingly in need of work. In 1910, the bridge was in such poor condition that it had to be largely rebuilt with the assistance of the Boston & Maine railroad (*Portsmouth Herald 3*/14/1910:1). In 1920, the Boston & Maine bridge and building crew were back at the bridge, "replanking and putting in much new timber" on the railroad section of the bridge (*Portsmouth Herald* 11/19/1920:1).

By 1921 things were in poor shape again. In August, a car went through what was later found to be a rotted railing. At this point, there was a push for an entirely new "permanent" bridge. Leading the effort were Portsmouth's mayor, F.W. Hartford and his newspaper, the *Portsmouth Herald* (*Portsmouth Herald* 5/13/1922:1). Large headlines in the *Herald* read, "Council to Issue Bonds to Rebuild Sagamore Bridge—Bridge Engineer States Structure Unsafe and Badly Decayed" and "Council May Build New Bridge at Sagamore" (*Portsmouth Herald* 12/15/1922:8). Mayor Hartford urged the City Council to move forward on a 30' concrete span (with or without a dam) that "would last for a thousand or more years with no upkeep to speak of" (*Portsmouth Herald* 12/15/1922:12). The *Herald's* push for a new bridge at Sagamore Creek was in keeping with the newspaper's boosterism of Portsmouth and its interest in improving Portsmouth, in particular its bridges.[3] However, soon after Samuel Ladd, a critic of the free-spending of Hartford's administration, took over as mayor in January 1923, the Portsmouth Public Works budget was slashed and the money for a new Sagamore Bridge was lost (*Portsmouth Herald* 3/9/1923:1). In danger of being permanently closed, a patch job was done on the Sagamore Bridge once more. The "temporary repairs" included tearing up the existing plank, driving new pilings and "mak[ing] such repairs that will keep the bridge fit for railroad traffic for a year or until the time the city decides to put in the new concrete bridge" (*Portsmouth Herald* 3/9/1923:1).

[2] See *Career of Hon. John Pender of Portsmouth, New Hampshire, Father of the Ocean* Boulevard a brochure at the Portsmouth Athenaeum, also Garvin 2004:, 5-7.

[3] *The Herald*, and its publisher (until his death in 1938) F.W. Hartford, was one of the most important players in promoting the construction of Portsmouth's Memorial Bridge and later the Interstate Bridge (Preservation Company 2009A,B).

In 1935, a new Sagamore Bridge was recommended as part of a route for a potential highway running "from the Massachusetts state line to the southern extremity of Portsmouth." This route, which was never acted upon, was identified as a possible PWA project.[4]

Planning the Present Sagamore Creek Bridge

Despite the assumption in 1928 that it would be only a few years before Sagamore Bridge would be replaced, the City was not to find a way to fund a new Sagamore Bridge for another fifteen years. The final and successful drive for a modern bridge at this location began in 1938. In August of that year the *Herald* ran an editorial once more pushing for a new bridge:

> A chain is only as strong as it weakest line… likewise a highway is only as safe as its most obsolete bridge. We are thinking of one of the most heavily-traveled highways in the state, the drive along the beaches on Route 1-A. The weak link in that chain is well-known to every resident of this area. It is the old Sagamore Creek Bridge in this city. The condition of this old wooden bridge is not satisfactory for bearing the weight and rush of present-day traffic. When the wooden planking is wet with rain this bridge also presents a peculiarly dangerous situation, causing cars to skid in an unaccountable manner… A new bridge at Sagamore Creek, of modern steel and concrete construction, together with whatever changes in its location and approaches as shall be necessary… is a necessity that should have the attention of the State Highway Department as soon as possible (*Portsmouth Herald* 9/29/1938:4).

By the time of this editorial, J[ustin].D. Hartford of Rye was publisher of the *Herald*, having succeeded his father F.W. Hartford after his death in July 1938. To promote the new bridge, the *Herald* took a regional approach and joined forces with the New Hampshire Seacoast Regional Development Association.

The New Hampshire Seacoast Regional Development Association was organized around in the mid-1930s by "15 towns, two cities and four incorporated precincts" (*Portsmouth Herald* 2/4/1938:1). It was one of at least two regional planning/development groups that were partially funded ($2500 annually) by the State Planning and Development Commission during this era. During this "golden era" of state planning, the state planning office was headed up by Frederick P. Clark who worked closely with the regional group.[5] In addition to the state funding,

[4] The proposed road would have hugged the coastline to the south on both new and existing right-of way then would have jogged over to Brackett Road before cutting over to Sagamore Road at Foye's Corner. Also described as part of the same proposal was an intersecting highway leading from Little Boars Head westward around Portsmouth meeting up to the (then) new General Sullivan Bridge between Newington–Dover bridge. These proposals in some ways anticipated the Route 1 Bypass (1940), I-95 (1950), and the Spaulding turnpike (1956-7) (Anonymous 1935:1).

[5] Clark was a nationally prominent planner of the era. He was director of the New Hampshire's planning office between 1936 and 1942 and one of the youngest persons to head a state planning agency. During his tenure in New Hampshire he worked on issues as varied as public recreation and airport development and his agency was responsible for producing dozens of studies. He was particularly well-known for his role in moving the town of Hill

additional support for the group came from the municipal members and from dues from individuals and business members (*Portsmouth Herald* 2/4/1938:1). The objectives of the association were "the development of agriculture, industry, recreation and education in the seacoast region" and "to bring the people of the seacoast region together so they will cooperate and coordinate their efforts to preserve and advertise this section" (*Portsmouth Herald* 6/1/1938:12; *Portsmouth Herald* 6/7/1936:5). Major projects that the group worked on in this era included the Hampton Beach Bathhouse, the jetties at Rye Harbor, and the promotion of a park at Odiorne Point. Although in general the group focused on tourism and development, it was involved in issues varying from emergency preparedness, to water pollution prevention. At the request of Clark, in 1940 the group became involved in comprehensive planning.

Perhaps as part of the planning initiative, at a meeting of the Seacoast group in June 1940, Secretary Alvin T. Redden was instructed "to write to the state highway department asking cooperation in obtaining a new bridge over Sagamore Creek on Route 1-A" (*Portsmouth Herald* 6/13/1940:2). Thereafter, Ernest A. Tucker[6] of Rye, chairman of the association's highway committee, after spending several months holding "many conferences with state officials," was successful in convincing the department to replace the bridge. In August, *the Herald's* headline read, "New Bridge to be built at Sagamore Creek." The accompanying photo showed chief State Highway Engineer Daniel Dickinson, J. D. Hartford, publisher of the *Portsmouth Herald*, Harold Langley, assistant chief state highway engineer, and Alvin Redden of the Seacoast group in front of the old Sagamore Bridge. In this and later articles, the *Herald* gave full credit to Tucker and the Association for convincing the state to build the bridge (see also *Portsmouth Herald* 12/26/1940:1). According to the article also, it was the group's recommendation that the new bridge be built slightly upstream from the original location, both so that traffic would not need to be rerouted during the new bridge's construction and to "enable the highway department to straighten out several bad curves at the approaches to the bridge" (*Portsmouth Herald* 8/15/1940:1). The new design eliminated "bad curves" on the approach and the older bridge's treacherous wood surface. The article anticipated a January 1, 1941, construction start date. A hearing on the state's plans for the bridge was held September 30, 1940, before the army engineers and in November the War Department approved construction of the bridge (*Portsmouth Herald* 11/2/1940:10).

Designers and Contractors for the Bridge

Two New Hampshire Highway Department engineers collaborated on the design of the bridge, largely in November 1940. John H. Wells was responsible for the superstructure and Harold Langley was responsible for the piers and abutments. Wells graduated from Worcester Polytechnic Institute in 1930 and began his career as an engineer with the New Hampshire State Highway Department shortly thereafter. (His initials appear on 1935 state bridge plans.) While at the State, amongst others, he is known to have worked (with Langley) on several important long-span bridges including the Chesterfield-Brattleboro Bridge (1937) [Chesterfield 040/095,

(*Portsmouth Herald* 2/14/1942). Clark went on to become Director of the Regional Plan Association of New York City, serve on the faculty of MIT and start his own consulting business (*New York Times* May 17, 1968).

[6] At least one *Herald* articles references Ernest **E.** Tucker. Ernest E. Tucker (1910-2005) was the son of Ernest A. Tucker; both father and son appear to have been involved in civic affairs in Rye.

Bypassed] and the Orford-Fairlee Bridge (1938) [Orford 062/124] arches over the Connecticut River, for which awards were given by the American Institute of Steel Construction. He also worked on the Woodstock tied arch over Pemigewasset River built in 1939 [Woodstock 177/148]. He worked in the Bridge Division until at least 1957. By 1970, he was the Chief structural engineer at Jackson & Moreland, in Boston.

During this time Langley was the state's Assistant Bridge Engineer. Langley attended MIT in the mid 1910s. In 1919, he began work with the state and at least by 1922, he was designing bridges for the Bridge Division. He was a prolific designer in the 1920s and '30s being responsible for "dozens if not hundreds" of bridge designs for the state in this period (Garvin ND). He was Assistant Bridge Engineer in 1922 and served as State Bridge Engineer, from 1942-61 (*Portsmouth Herald*, 9/22/1961:14). In 1943, Langley revised Hool and Kinne's classic *Moveable and Long-Span Steel Bridges* and included both a photo of and discussion of the Sagamore Creek Bridge. Among his best-known bridges were the two through-arch bridges he worked on with Wells, the prize-winning Chesterfield-Brattleboro and Orford–Fairlee Bridges. Langley was particularly known for his expertise with arches, concrete, and steel (Garvin ND).

Bids for the project were opened and the project awarded, on December 5, 1940. The successful bid of $110,000 was made by the O.W. Miller Company of Ludlow, Massachusetts. The O.W. Miller Company was active from the mid-1930s through the mid 1950s in New England. The company was founded by Oliver Walker Miller (1886-1940) apparently in the early 1930s. The son of a Ludlow, Massachusetts, carpenter, Miller apparently lived largely in Massachusetts with the exception of a brief period during WWI in the south. The company appears in City Directories for Springfield, Massachusetts, for the first time in 1935, but predated this as it was the contractor for a bridge in Vermont in 1932 and a bridge in Rumney, New Hampshire, in 1934 (Garvin 1999A). The company continued in operation after Miller's death, into the 1950s. Miller's son, also O.W Miller, worked for the company until founding his own company (Miller Construction Inc.) in Windsor, Vermont, in 1946. The O.W. Miller Company was the contractor for a number of post-1936 Flood bridges. In 1937 the company completed four major bridges in (or partially in) New Hampshire, including three bridges over the Connecticut River (the Chesterfield/Brattleboro Bridge, the Monroe/Barnet Bridge, and the Lyme/Thetford Bridge). They completed a 175' tied through arch bridge in Woodstock over the Pemigewasset River in 1939, bridges in Hinsdale and Danbury in 1940 and a large multi-span rigid frame reinforced concrete bridge in Franconia in 1941.

The bridge was fabricated by the American Bridge Company which specialized in steel spans. The company was founded in 1900 by J.P. Morgan & Co. and was a textbook example of the growth of monopolies in the early twentieth century. In its first year of existence the company purchased some twenty-four bridge companies, representing half of the country's fabricating capacity (Darnell 1984). The next year, the company became a subsidiary of the United States Steel Company, although it continued to operate under its own name as a separate division. The company completed projects throughout the country including buildings and bridges varying from the Hell's Gate Bridge, and Oakland Bay Bridge to the Empire State Building. In New Hampshire, the company was involved with a number of key bridges. In 1921, it was the contractor for the superstructure for the original Memorial Bridge between Portsmouth and

Kittery (1921), a vertical lift bridge designed by J. A. L. Waddell. The company was particularly active in the state after the 1927 and 1936 floods. After the former, it built or fabricated at least eighteen bridges in the state, after the latter it built at least nine bridges in the state (Garvin 1999A).

Construction and Alterations to Sagamore Creek Bridge

The Miller Company started work at the site on December 26, 1940, with the *Portsmouth Herald* reporting that "steam shovels, surveyors, telephone and electric lineman [were] all assembled…" (*Portsmouth Herald* 12/26/1940). By May 13, 1941, the *Herald* reported that some of the steel scheduled to be transported to the Breakfast Hill station of the B&M was delayed due to the "national defense program." The delay in the steel delivery appears to have been minor since the paper reported that in June and July a number of small fires were ignited on the old bridge by welding equipment being used on the new bridge's superstructure (*Portsmouth Herald* 6/10/1941).

The new Sagamore Bridge opened quietly on July 1, 1941, five months before Pearl Harbor, without fanfare. Trying to finish the bridge to accommodate Fourth of July traffic, the bridge went into operation without ceremony (*Portsmouth Herald* 7/2/1941:3). Although there was discussion of a dedication, in the wake of the increased war effort, none apparently took place.

Since the bridge's completion, there were relatively few alterations. The bridge was cleaned, primed and spot painted in 1948 and 1953. In 1970, Edward J. Baker Co. of Framingham, Massachusetts, was low bidder on a project to replace the original cable and wood post guard rail and pave the shoulders on the approaches to the bridge (*Portsmouth Herald* 8/5/1970:48). Three years later the bridge was again cleaned, primed and painted and a steel bridge rail replaced the original, and bridge shoes and grid flooring were replaced (*Portsmouth Herald* 7/31/1973:3).

In 1984, the Bridge had a more significant rehabilitation. For the substructure, the concrete backwalls and wings were repaired and stone fill placed in front of the abutments. In terms of the superstructure, the floorbeams were replaced, portions of the steel grid floor were replaced, new studs were added to the bridge floor, cross-frames, lateral bracing and gussets were repaired as needed and the structural steel was cleaned and painted. In addition, the original pipe and paling railing was replaced.

Defense/World War II Context of the Sagamore Creek Bridge

Beginning with the construction of the predecessor bridge in 1850, the Sagamore Creek Bridge served a key role in the Portsmouth region's transportation network. The crossing represented the fastest route between Portsmouth and points south such as Rye, in particular to the beaches and seashore. It also served as an important transportation link to the many coastal military facilities which were concentrated along the east side of New Castle Island and the area between Frost Point and Odiorne Point south of Sagamore Creek.

The history of coastal defenses in the Portsmouth area dates back to 1631 when the first defenses to protect Portsmouth Harbor were built at Fort Constitution (originally Fort William & Mary) on the north end of New Castle Island. Fort Stark, located on the south end of New Castle Island was fortified beginning in 1746. Camp Langdon, located halfway between these two forts, was acquired by the Army beginning in 1909; it went through a major construction program in 1940 that included twenty-eight buildings including barracks. In Rye, just south of New Castle, the land for Fort Dearborn along the waterfront between Odiorne Point and Frost Point in Rye, was only condemned in 1942; it served as a headquarters, training and a base/living camp during WWII.[7] In addition to these larger facilities, there were multiple small fire control towers (base end camps) and radar stations sprinkled along the coast.[8] During WWII all of these facilities were charged with defending Portsmouth Harbor, and as such, defending the Portsmouth Naval Shipyard which during WWII had immense importance to the war effort and at its height employed some 22,000 workers. Since many of the men from the coastal facilities south of Portsmouth Harbor were largely housed at Fort Dearborn, a tremendous quantity of men, machinery and trucks made daily trips along the coastline on Routes 1A and 1B. Sagamore Bridge was part of the main route between Portsmouth and Fort Dearborn/Odiorne Point and was a secondary route between Portsmouth and the New Castle facilities.[9]

Because much of the buildup in the seacoast defense system began after the new Sagamore Bridge was already on the drawing boards however, it is difficult to directly tie the bridge's construction to defense needs. Before its construction, contemporary newspaper articles do not appear to link the need for the new bridge to defense. But the world changed significantly soon thereafter. In February 1940, with United States allies on the other side of the Atlantic threatened, the 22nd Coast Artillery Regiment of the Army was activated and in September 1940 troops arrived at Fort Constitution to man coastal defenses for the first time in twenty years (Wysong 1997:12; *Portsmouth Herald* 9/12/1940:1). By January 14, 1941, a *Portsmouth Herald* article reported that there were more than 1,000 construction workers at the New Castle bases and, "the Wentworth and Sagamore roads leading from New Castle and the Portsmouth Harbor defenses are fast becoming carbon copies of the road from the navy yard to Portsmouth during the rush hour…" Despite that fact that its inception was not directly linked to defense, the bridge was a key component of the defense transportation network, and in the days after the bridge's opening it appeared repeatedly in lists of Portsmouth's Defense Projects (*Portsmouth Herald* 7/8/1941:10 see also *Herald* 7/16/1941:4 and 7/23/1942:4).[10]

---

[7] In New Castle, the site of Fort Constitution is 25 Wentworth Road; Fort Stark was located at 211Wildrose Lane and Camp Langdon was located at 301Wentworth Road. Fort Dearborn's current location would be 570 Ocean Boulevard, Rye. The troops at these facilities were largely from the 22nd Coast Artillery Regiment of the U.S. Army Coast Artillery Corps.

[8] Base end camps were located at Great Boars Head, (Dumas Avenue) Hampton Beach, Rye Ledge, Ocean Boulevard, Rye, and Pulpit Rock (Neptune Drive) Rye. Radar Stations were located at Concord Point and Ragged Neck in Rye.

[9] During the war, traffic in the area was further complicated by the fact that Ocean Boulevard adjacent to the Fort Dearborn military reservation (roughly Brackett Road to the north and Wallis Sands to the south) was closed to non-military traffic.

[10] Although not discussed in contemporary newspaper articles, it is possible that defense issues were helpful in convincing the state – the sole source of the bridge's funding – to construct it.

Development of the Plate Girder Bridge & Continuous Deck Girder Subtype

Sagamore Creek Bridge is an example of a riveted steel continuous variable-depth plate girder deck highway bridge dating from the developmental years of the type, which began about 1930 and culminated in the 1940s. During the 1950s and 1960s welding significantly altered the engineering characteristics of the bridge type allowing the use of lighter all-welded girders and orthotropic and composite deck systems. The history of the development of the Sagamore Bridge type begins with the origin of the plate girder bridge, follows the development of the deck plate girder highway bridge and the continuous plate girder bridge, and concludes with the application of the type in New Hampshire.

Plate Girder Bridges

A plate girder is I-shaped in section, "built up" or assembled with steel plates and shapes that are riveted, bolted, or welded together to form a deeper beam than can be produced by a rolling mill. In its simplest form, a plate girder consists of a rectangular steel plate (the web) in the vertical position, to which flanges are riveted or welded along the top and bottom edges. The flanges may consist of an assemblage of angles and plates in a riveted girder, or a single plate in a welded girder. Typically, top and bottom flange cover plates and vertical web-stiffener angles at the ends and intermediate points are added for greater strength. Each additional cover plate is usually made progressively shorter and centered on the girder to increase the cross-sectional area of the girder near the middle where the bending moments are the greatest.

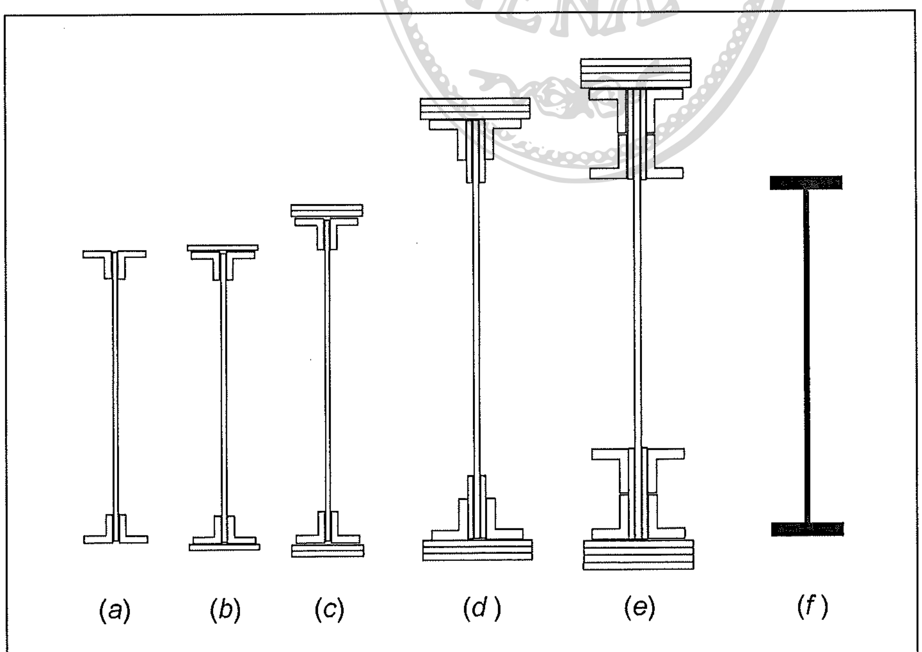


FIGURE 1: Typical Bridge Plate Girder Construction
(*a*) Simplest type of riveted plate girder with web plate and four angles forming flanges

(*b*) Short span type with one full length flange cover plate
(*c*) Medium span type with multiple cover plates of varying lengths
(*d*) Long and heavy spans, esp. railroads, with extra vertical side plates and multiple cover plates
(*e*) Extra heavy railroad spans with added flange angles, side plates and multiple cover plates
(*f*) Simplest type of modern welded girder of three plates

In 1847 the first simple span, wrought iron plate girder bridge was erected in America for the Baltimore and Susquehanna Railroad by James Mulholland. Plate girders were widely adopted by the railroads for simple spans up to 100' throughout the nineteenth century, and by 1906 all but an insignificant percentage of short span railroad bridges were of plate girder construction (Hill 1882:109; Skinner 1906:4).

In explaining the popularity of simple-span plate girders, bridge engineer Frank Skinner states that

> the stresses in plate girders are somewhat indeterminate and the weight of materials is generally in excess of the theoretical amount required except in very short spans, but they are largely used instead of trusses because of their simplicity, ease of construction, shipment and erection, durability and less liable to injury by accident, more effective mass and rigidity, and best suited for use into positions of small clearance. Almost exclusively used for spans of 30-60 feet, generally used for spans 20-100 feet and occasionally for spans up to 130 feet, and almost exclusively for spans 30 to 60 feet (Skinner 1906:3-4).

Trusses were still preferred for long spans for several reasons. Efficient use of material, and therefore lower cost, is the mark of a good design, and on longer spans the waste represented by the excess material in the solid web of the plate girder became significant. Truss bridges could be assembled at the plant and disassembled for shipment, unlike girders, and girders could not be transported or handled in one piece much beyond 100' in length; also, the extensive field riveting necessary to splice a girder was impractical prior to the invention of the air-powered rivet gun in the late nineteenth century (Kunz 1915:15).

In 1900, 24" deep I-beams were the largest the rolling mills were capable of producing. Mills gradually increased in capacity and by the mid-1930s standard-production rolled beams were available up to 36 inches deep, 60 feet long and weighing 300 pounds per foot (Fuller & Kerekes 1936:107). These deep rolled beams, with wide flanges for increased strength, were less costly than labor-intensive riveted plate girders and replaced them in many circumstances. The refinement of automated welding machines after World War II and the application of x-ray technology to inspect welds, led to the widespread adoption of welded plate girders over riveted girders during the second half of the twentieth century.

Plate Girder Highway Bridges

During the 19th century and early years of the 20th century, plate girders bridges were used primarily by the railroads which could economically transport and handle their massive size and weight.[11] When used for highway bridges, the most common application was for railroad overpasses where they were easily delivered by rail and lifted into place by a derrick car. Even for fairly short-span highway bridges, trusses remained more popular due to their lighter weight, which equated to lower material cost, lower transportation cost, and usually lower erection cost.

The earliest example of a plate girder highway bridge found in the engineering literature is the Dean Road Bridge over the Boston & Albany Railroad tracks in Brookline, Massachusetts, built in 1891 by the Town of Brookline. It was a through bridge, with girders "about 63' long, 4 ft. 9 ins. deep at the ends and about 6 ft. at the middle with the top chord curved to a radius of 318 feet" (*Engineering News Record* September 19, 1891:257). Each girder weighed 10 tons and was hoisted into place by a rail steam derrick. When a highway was elevated to pass over the railroad, overpass bridges were usually of the through bridge design (roadway carried on the lower flanges and passing through the girders) to limit the height of the abutments and amount of filling required in the approaches. Through bridges are also commonly used when passing over streams with low banks to provide the maximum under clearance to accommodate floods.

In the early part of the 20th century, plate girders were considered "not well adapted to country highway bridges" due to their excessive strength even in their lightest form and because of the "difficulty in hauling plate girders of any considerable length over country roads" (Wells 1913:72-73). But plate girders had advantages in terms of simplicity and standardization of design, ease and speed of erection, and greater durability, which equated to lower maintenance and life-cycle cost. They were the practical and often economical choice for highway bridges in certain situations including railroad overpasses to eliminate crossings at grade and urban bridges with heavy dead or live loads due to a great width, masonry-paved roadways or the addition of street railway tracks.

By 1908, designs for plate girder highway bridges up to 109' span were appearing in engineering textbooks and steel fabricators including the American Bridge Company were offering pre-engineered standard production plate girder highway bridges in various lengths.[12] During the

[11] Discussion of plate girder highway bridges in the engineering literature prior to 1900 is rare. Structural engineering and bridge design texts typically provide examples and design specifications for plate girder railroad bridges only and in brief passing mention the application of the plate girder for highway bridges. William H. Warren in *Engineering Construction in Iron, Steel and Timber* (New York: Longman Greens & Co., 1894) does not mention highway plate girder bridges. Johnson, Bryan & Turneaure in *Theory and Practice of Modern Framed Structures* (New York: John Wiley and Sons, 1894) in their discussion of web-plate thickness state "in light work, as for highways, a minimum thickness of one forth inch may be used up to a depth of 5 or 6 feet" (p. 325). Nearly the same statement is made by Merriman and Jacoby in *A Text-Book on Roofs and Bridges, Part 3* (New York: John Wiley and Sons, 1894, p.107), except that 5/16 of an inch is specified as the minimum for highway bridge plate girder web plates. Neither discuss of give examples of plate girder highway bridges.
[12] See (Ketchum 1908: 222-224); a plan for a standard 80' span through plate girder highway bridge with a solid reinforced concrete floor available from American Bridge Company is reproduced therein.

second decade of the 20th century, state highway departments were formed and staffed with bridge engineers who developed standard short span bridge designs in steel and concrete. The designs were often made available to county and towns governments free of charge to promote economical and safe bridge construction (Parsons Brinkerhoff Quade & Douglas, Inc. 1997: 3-11; *Engineering Record* 61 (January 22, 1910):89-90; *Engineering Record* 61 (March 19, 1910):318. By 1920, the Wisconsin Highway Commission for example, had prepared standard plans for plate girder highway bridges in five-foot increments from 35 feet to 80 feet (Ketchum 1920:167).

Having standard plate girder highway bridge designs on hand saved engineering time and allowed for fast replacement of old lightweight steel truss bridges or wood beam bridges that were failing or bridges destroyed by floods. Plate girder bridges could be ordered and delivered within weeks and dropped into place on the existing abutments with often only minor alterations to the substructure.

Deck Plate Girder Highway Bridges

Deck plate girder highway bridges date to at least 1894. Deck bridges, where the roadway is carried on the top flanges, are usually more economical than a through bridge and possess several inherent advantages particularly for highway applications. According to renown bridge engineer J.A.L. Waddell, "whenever there is a real choice between a deck structure and a through structure for any crossing, or any portion of a crossing, the deck structure will nearly always be found the more economical for two reasons: first, the piers for the deck bridge will be lower, shorter and smaller than for the through bridge; and second, there is often, but not always, a saving in the cost of the superstructure" (Waddell 1927:2).

Probably the greatest advantage of the deck design for highway bridges is their ability to be easily widened. Deck girders also allow for closer spacing of the girders, which in turn allows the floorbeams to be cantilevered beyond the girders to carry part of the roadway or sidewalks with a resultant cost savings. Other advantages of deck bridges: easier snow removal, the girders not subject to damage from collisions and the flanges and web are better protected from weather and corrosive agents.

By the 1930s the deck bridge had become the preferred type for highway bridges. With the dramatic increase in the number and speed of automobiles another important advantage of the deck type became more apparent to highway engineers. Unlike a through bridge, a deck bridge provides an unobstructed view, creates less anxiety in the motorist in terms of feeling hemmed in, and allows greater speed and safety because the optical illusion of a narrowing roadway is almost entirely eliminated (Ogden 1937:402-405).

Continuous Plate Girder Bridges

A continuous girder is supported at three or more points along its length. The structural advantage of the continuous girder over a simple span, which is supported only at its ends, results from the bending forces created in the beam over the piers, which counteract and reduce the bending forces in the center of the span.

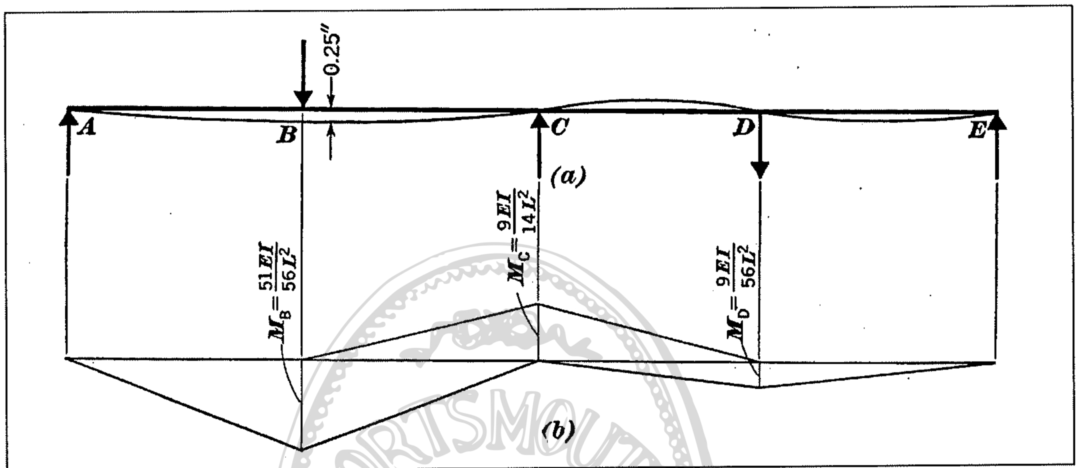


Figure 2: Continuous Beam Deflection Diagram.

Figure 2 shows a continuous beam (or girder) supported at three points, A, C and E, representing piers or abutments in the case of a bridge girder. In this textbook example, a load applied at point B to the beam between supports A and C, deflects the beam downward, resulting in both an upward and downward deflection of the beam between supports C and E. Engineers can utilize this principal of beam continuity to achieve several practical advantages in their bridge design, including economy of material, erection without falsework, and increased rigidity under traffic Lindenthal 1932:421; Skinner 1906:3).

During the 1930s the use of continuous girder bridges and other statically indeterminate structures increased as a result of advances in mechanical and photoelastic methods of checking stresses in models. Bridge engineers within state highway departments were chiefly responsible for the adoption of the continuous plate girder bridge form because it was the most economical solution for most elevated and medium span highway bridge applications.

Cost savings of 10 to 30 percent over simple span structures were realized in the structural steel, the elimination of expansion joints and a reduction in the number of rockers and bolsters. The greater rigidity reduced deflections by about 50 percent allowing shallower concrete deck construction. Additional savings were obtained by reducing the size of the pier caps, elimination of some end floor-beams, and the opportunity to increase the economical span length of the plate girder.

By 1940 the continuous plate girder deck highway bridge was widely used across the United States by state highway departments because of its many attractive cost and engineering features. Over the second half of the 20th century the continuous deck girder bridge became one of most widely used steel bridge types in the world.

Variable Depth Girders

Variable depth girders are girders with non-parallel flanges. Either flange can be shaped to follow variations in the depth of the web, but most common are the curved or "arched" bottom flanges of girders that are deeper over their bearings than at their midpoint. The arch effect may be uniform, following the radius of a large circle, or have multiple radius centers such as an elliptical arch. Some continuous girders were abruptly deepened over the piers creating a hump known as the haunch of the girder; the term haunch became generally used for the deepened section of the girder regardless of its shape.

The Dean Road Bridge (discussed above) is the earliest example found of a simple plate girder span[13] with variable depth girders, described at the time as "girders with non-parallel flanges" (*Engineering News* September 19, 1891:257). The terminology for naming or describing variable depth girders is inconsistent in the literature. In 1906 Skinner describes a bridge with variable depth girders as having "horizontal top flanges and curved bottom flanges" (Skinner 1906:323). Waddell (1913) also resists assigning a name to the sub-type and simply differentiates between "girders with parallel flanges" and "girders with flanges not parallel" (Waddell 1916 Vol. 1: 433). Other writers have referred to girders with "curved" or "inclined" flanges, or simply "variable depth" girders (Bond & Ellis 1960:55). [Note: The term "variable section girder" was apparently coined by one of the authors of the New Hampshire historic bridge survey in the 1980s to describe girders that vary in depth along their length. It was not found anywhere else in the technical engineering literature and is a misnomer since "section" as used by engineers typically refers to cross sectional area and parallel flange girders with multiple, progressively shorter cover plates are also girders with "variable sections" along their length.]

Varying the depth of a girder makes more economical use of material by increasing or decreasing the depth of section of the girder to coincide with the stresses at various points along its length. However, curved flanges and web plates required additional and careful fabrication steps, the cost of which usually exceeded any savings in material cost until the adoption of welding. Although more expensive to fabricate, curved bottom flanges on deck plate girders decreased deflections on longer spans with the added benefit of providing a more pleasing arched shaped (variable-depth girder) appearance (Smith 1939:59-61).

Bridges with simple span plate girders of variable depth occur used in the early 20th century, their use being primarily for aesthetic reasons like parkway overpass bridges, or in circumstances where maximum clearance under the center of the span was required but the grade of the bridge deck needed to be kept to a minimum, as in a railroad passing over a railroad. The same formulas are used in the design of variable depth girders as those with parallel flanges, providing the slope angle is less than about 10 degrees, but many repeat calculations are required along points of varying depth.

---

13 Simple girder spans are beams supported only at each end, as opposed to continuous girder spans which are beams having one or more intermediate supports.

New Hampshire Plate Girder Bridges

The first plate girder highway bridge in New Hampshire was the Tappan Street Bridge over the Mad River in Farmington (replaced 1992), a through span believed to have been built about 1900 (Moore? 1988A). The Walpole-Westminster Bridge over the Connecticut River, built 1911, replaced 1989, was a three span through plate girder bridge with two cantilever spans and a suspended pin-connected center span. The cantilever spans were variable-depth girders with the bottom flange curved to form a low arch. It was an innovative design by renowned engineer Joseph R. Worcester of Boston. His most famous bridge was the monumental Bellows Falls Steel Arch Bridge built over the Connecticut River in 1905, replaced 1983 (Closs 1988).

Probably the first deck plate girder highway bridge in New Hampshire was a two-span structure built in 1915, replaced 1981, to carry Broad Street over the Sugar River in Claremont. It was designed by Storrs and Storrs of Concord and erected by United Construction Company of Albany, New York (Moore? 1988B).

During the 1920s the majority of bridges constructed by the State Highway Department were of reinforced concrete. Prior to the great flood of November 1927, only two plate girder bridges were constructed, both built in 1926: the Newfields-Stratham Swing Bridge over the Squamscott River, a through plate-girder center-bearing manually operated swing span with one through plate girder approach span, replaced 2001; and a 91' span plate girder on Crawford Notch Road in Hart's Location, replaced 1976 (Louis Berger 2000; NH State Highway Department 1927:76).

Among the many replacement bridges built with Flood Emergency funding in the wake of the 1927 flood were nine plate girder bridges. All the superstructures were built by American Bridge Company except for the Hart's Location Bridge that was built by the Standard Engineering and Construction Company (*New Hampshire Highways*, June 1928).

NH Flood Emergency Plate Girder Highway Bridges Built 1928			
Town	**Location**	**Spans – Lengths**	**Extant?**
Bethlehem	Gale River	1 - 65'-10"	Replaced 1990
Carroll	Little River	1 - 65'-10"	Replaced 1990
Campton	W. Campton	2 - 105'-4"	Extant
Campton	Branch Brook	1 - 85'-4"	Extant
Carroll	Fabyans	1 - 97'-4"	Replaced c.1987
Gorham	Moose Brook	1 - 53'-4"	Replaced c.1975
Hart's Location	Saco River	1 - 94'-0"	Replaced 1976
Rumney	Baker River	1 – 97'-4"	Extant
Warren	Lane Brook	1 – 97'-4"	Replaced c.1976

In 1930 another large plate girder bridge was built in Franklin over the Pemigewasset River. Franklin Bridge 152/110, replaced in 1994, was 394' overall. Three of the five spans were deck plate girders. Simple-span riveted deck plate girders bridges continued to be built by New Hampshire when conditions favored them up through the 1960s when they were mostly phased out by welded girder bridges.

The use of continuous plate girder bridges in New Hampshire began in 1930 with Bartlett Bridge 203/172 [not extant], a 193' continuous plate girder bridge consisting of two 95'-0" deck spans. According to State Architectural Historian James L. Garvin:

> In 1931, the State Highway Department designed a continuous through plate girder bridge over the Connecticut River between Clarksville and Pittsburg [not extant], and another over the Saco River at Bartlett [not extant]. In 1934 and 1935, the department designed dramatic deck plate girder bridges over the Connecticut River, the first between Littleton and Waterford, Vermont [Littleton Bridge 109/134], and the second – the Ledyard bridge – between Hanover and Norwich, Vermont [not extant]. Both bridges were continuous structures with graceful girders of variable [depth] section, their curved bottom profiles giving them maximum strength at points of greatest stress. These Connecticut River bridges of the 1930s illustrate the evolution that has taken place in structural analysis and bridge design in the two decades since Worcester built the Walpole-Westminster bridge as a statically determinate structure. The Littleton and Hanover bridges became prototypes for other continuous deck plate girder spans: the Sagamore Creek Bridge in Portsmouth (1941), a bridge over the Boston and Maine Railroad and Mascoma River (1945) at Lebanon [Lebanon 077/107], and a bridge over the Saco River (1945) at Conway [Conway 170/071] (Garvin 2000 volume 2).

Comparative Analysis of New Hampshire Deck Plate Girder Bridges

In addition to the Sagamore Creek Bridge, there are 22 bridges in the NHDOT 2012 Bridge Summary classified as deck plate girder (DPG) bridges. The simple-span bridges, all with parallel flanges, include ten railroad bridges and three highway bridges, (Enfield 172/112, Gorham 092/058, and Lebanon 188/107). They do not compare closely to the Sagamore Creek Bridge and are not considered. The four Route I-93 bridges, built in 1959 over the Merrimack River and in 1960 over the Ammonoosuc River, and a bridge built in 1962 by the Army Corps (Surry 126/060), are roughly 20 years younger than the Sagamore Creek Bridge and are not chosen for comparison for that reason. Four bridges plus the Sagamore Creek Bridge remain for comparison as listed in the table below. Section drawings and photographs of the bridges are also included below.

All five bridges represent essentially the same technology with minor variations in the sizing and spacing of the structural components to achieve the particular design goals, the primary goal being lowest cost. The main center spans range from 138' to 160'; the side spans range from 114' to 126'. The amount of "arch" to the beams, the variation of the beam depth, can be compared by looking at the ratio of the maximum to the minimum girder depth. It ranges from 2:1 on the Conway bridge, to 1.1:1 on the Littleton bridge. The other three bridges have a girder depth variation ratio of about 1.5:1. There is nothing apparent to suggest there is any engineering significance to these variations. As the designer changes one structural component to take advantage of a particular economy, other components will change. The difference in the arch profile between the Littleton bridge and the others is substantial; a possible explanation may be the cost of fabricating variable-depth girders went down as the demand for them grew.

There are two primary features among the five bridges that are unique to only one bridge: the open steel grid floor used on the Portsmouth (Sagamore Creek) bridge versus the concrete slab floor used on the other bridges, and the three continuous plate girders with no floor beams used on the Stratford bridge versus the two girder/floor beam superstructure on the others.

The open steel grid floor used on the Sagamore Creek Bridge was of the "I-beam Lok" type according to the bridge card. The use of the floor by John Wells in the design was not exactly innovative, but, coupled with the field welding of components of the floor system, he was in the forefront of the application of lightweight floor systems to bridges. Various types of patented lightweight steel floors of the open grid type were brought to market during the 1920s, '30s, and '40s. The early types used flat and bent bars riveted together; others such as the I-Beam Lok manufactured by Carnegie Steel were tack-welded together to form a structural unit. The purpose of steel grid floors, also called open grate flooring and open mesh steel pavement, was to reduce the dead load on the bridge and thereby save structural steel and cost. Lightweight steel floors were quickly utilized for lift bridges for obvious reasons, and for suspension bridges where the majority of the cost of the cables is to carry deadweight. The monumental Bronx-Whitestone Suspension Bridge (1939) was equipped with the patented I-Beam Lok floor system. In addition to being lighter in weight, other advantages were claimed: resistance to skidding, absence of crown, better drainage and absence of snow and dirt accumulation. Drawbacks of steel grid floors are that they suffer from rivet and weld failures, accumulate dirt on the steel sills or supporting members and become slippery with wear.

Comparing the Sagamore Creek Bridge to the Conway bridge, built four years later, it can be seen that for essentially identical spans, the depth of the girders was less and their spacing wider on the Sagamore Creek bridge that used the lighter steel grid floor.

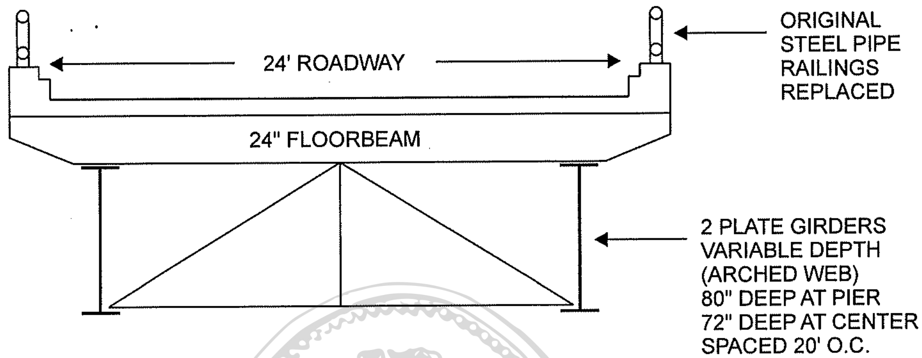
The three girders used on the Stratford Bridge represents the trend at the time toward the multi-beam (or multi-girder) design that eliminated the use of floor beams and made use of stronger reinforced concrete deck slab designs that in-turn enabled thinner decks with longer spans. Comparing it to the Conway bridge for example, the deck thickness was reduced by 1.5 inches, girder depth was slightly reduced, but most significantly loading was increased from H-15 to H-20 with complete elimination of the floor beam system. Although a different structural bridge type entirely, it is included in the comparison to show how John Wells made the leap to the next generation of deck girder bridge design just four years after his design of the Sagamore Creek bridge. In spans and profile, the Stratford bridge appeared nearly identical to the other bridges in the group, but without the distinctive cantilevered floor beams ends.

The evolution in roadway width from 24' to 26' to 28' over roughly a ten year period is also evident by comparing the data in the table and again reflects the ever increasing speed, size and number of vehicles using the roads. The Sagamore Creek bridge and the Lebanon bridge both used 21" x 59# wide flange floor beams but the ends of the Lebanon floor beams terminate in a quarter-round radius rather than the angle cut on the other three bridges. Both bridges are designed for H-20 loading but have different floor beam spacing, the narrower 4'-2" spacing on the Portsmouth bridge was to accommodate the specification of the open grid flooring.

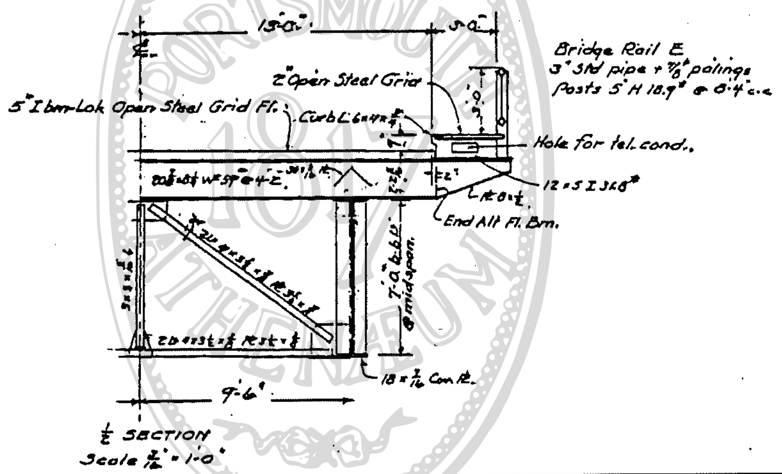
The piers and abutments on all the bridges are of conventional reinforced concrete design adapted for the particular requirements of the site, approaches and foundation conditions. The round reinforced concrete piers supporting the Sagamore Creek Bridge – the one bridge of the group standing in salt water – are interesting because they were armored with wrought-iron jackets to protect the concrete from the deteriorating effects of seawater. Typically this was done with granite facing and the use of the iron encasement raises the question as to why it was used. They resemble pipe piers popular in the early 20th century but apparently were not used in any structural role other than to protect the structural integrity of the reinforced concrete inside.

As shown on the section drawings, all of the bridges except Lebanon used NHHD Standard Railing "E" consisting of steel H-posts, pipe railing and 7/8" pailings (steel rod balusters). The Lebanon bridge railing was Type F, of aluminum construction.

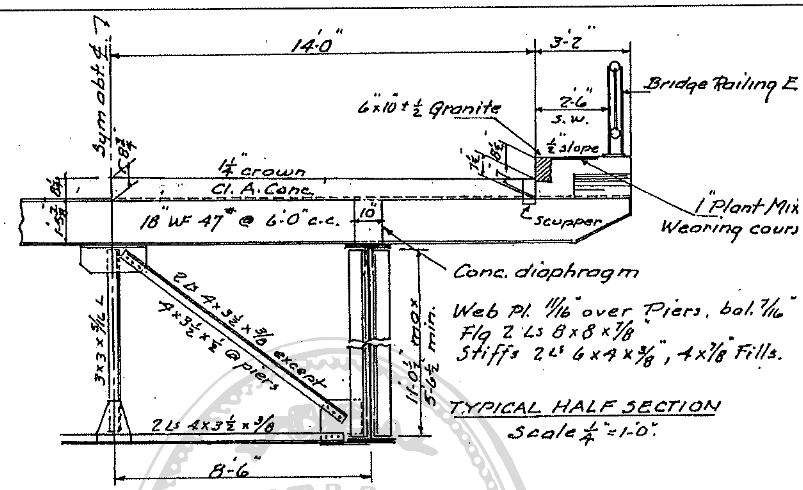
New Hampshire Continuous Deck Plate Girder Bridges With Variable Depth Girders				
BRIDGE	**CARRYING/OVER**	**DATE**	**REPAIRS**	**SPAN DETAILS**
Littleton 109/134	NH 18 over Connecticut R	1934	1980 deck rehab	- 3 spans 115'-138'-115' (plus 2 simple end spans) - 533 feet o.a. - 2 PGs, 20' c-c - PG depth 6.6" to 6' = 1.1 : 1 - FB 24" x 87# WF, 4'-2" c-c - concrete deck, 8.5"-9.5" - 24' roadway - H-15 design load - Designed by R. D. Field
Portsmouth 198/034 (Sagamore Creek Bridge)	NH 1A over Sagamore Cr	1941	1984 deck rehab	- 3 spans, 116'-158'-116' - 398 feet o.a. - 2 PGs, 19' c-c - PG depth 10.5' to 7' = 1.5 : 1 - FB 21" x 59# WF, 4'-2" c-c - 5" open steel grid deck - 26' roadway - H-20 design load - Designed by John H. Wells
Conway 170/071	NH 16 over Saco R	1945	1978 deck replaced	- 3 spans, 120'-160'-120' - 408 feet o.a. - 2 PGs, 17' c-c - PG depth 11' to 5.5' = 2 : 1 - FB 18" x 47# WF, 6'-0" c-c - concrete deck, 7.5"-8.75" - 28' roadway - H-15 design load - Designed by Ralph R. Kenny & Wendell H. Piper
Lebanon 077/107	US 4/NH 10 over Mascoma R/ BMRR	1945	1968 deck replaced	- 3 spans, 114'-150'-114' - 384 feet o.a. - 2 PGs, 18' c-c - PG depth 11.5' to 7.25' = 1.58 : 1 - FB 21" x 59# WF, 6'-0" c-c - concrete deck, 8.5"-9.5" - 28' roadway - H-20 design load - (Designer unknown)
Stratford 029/206	VT 105/Bridge St. over Connecticut R	1947	2000 deck rehab	- 3 spans, 126'-160'-126' - 420 feet o.a. - 3 PGs, 12.5' c-c - PG depth 10.6' to 6.5' = 1.6 : 1 - no Floor Beams - concrete deck, 7.0"-8.0" - 28' roadway - H-20 design load - Designed by John H. Wells



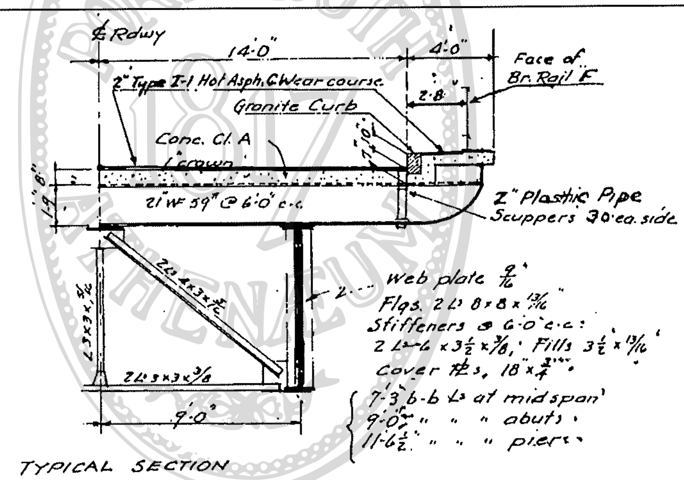
Littleton 109/134 - 1934



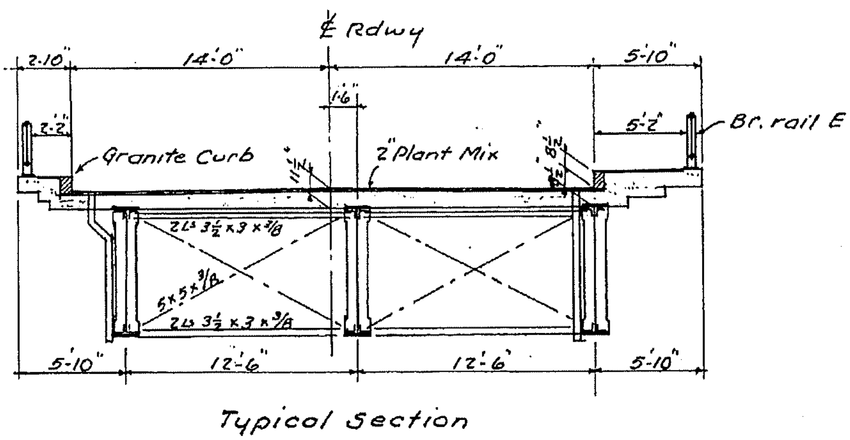
Sagamore Creek Bridge (Portsmouth 198/034)- 1941



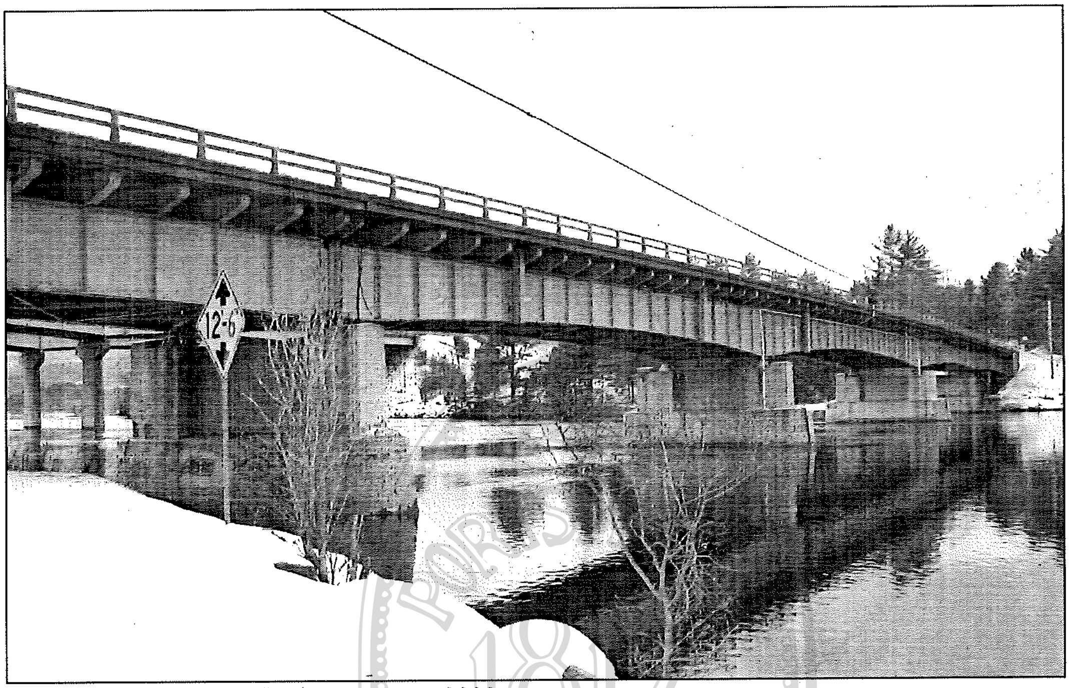
Conway 170/071 - 1945



Lebanon 077/107 - 1945



Stratford 029/206- 1947



Littleton 109/134 [1934]. Photo January 2008

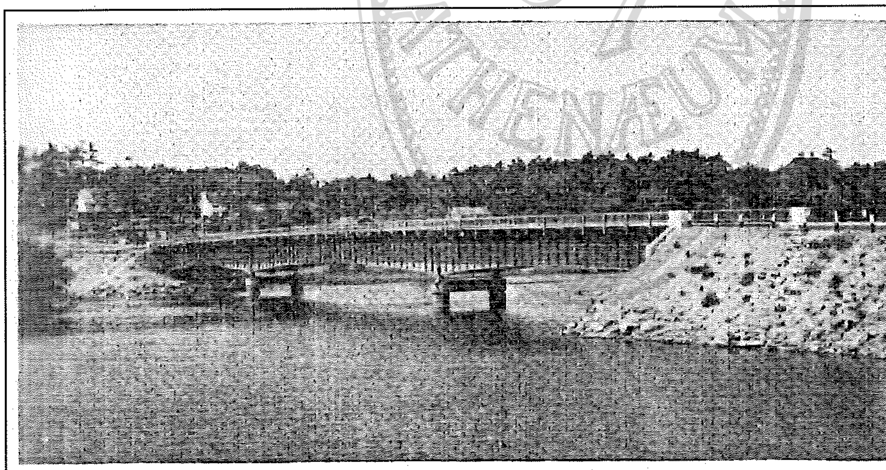
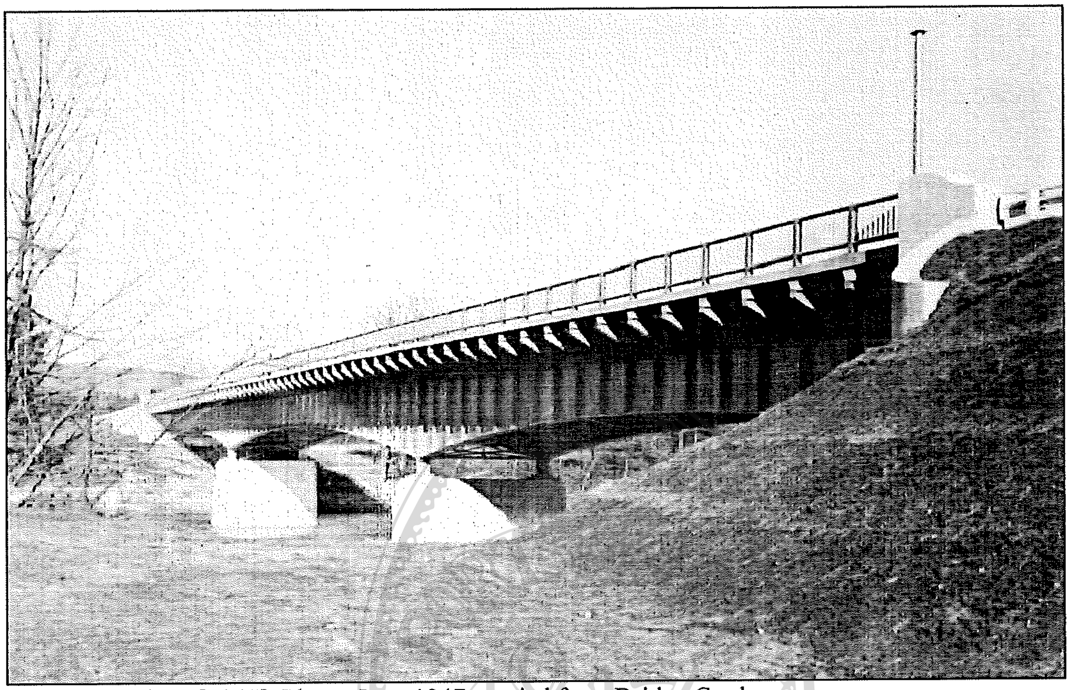
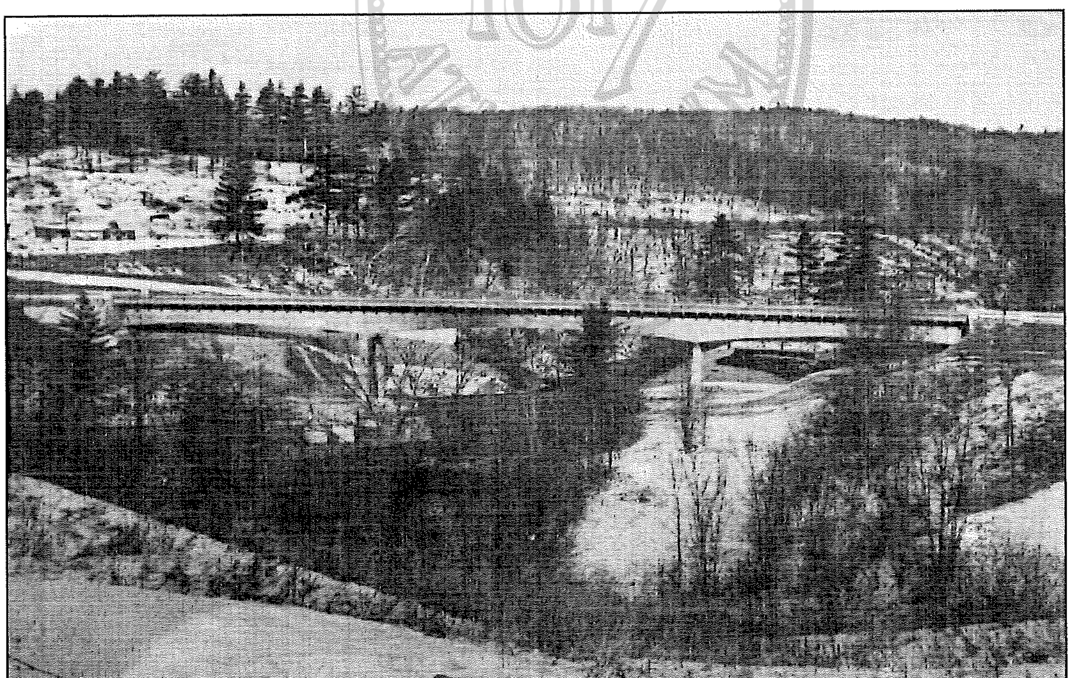


Fig. 34.—Sagamore Creek Bridge, New Hampshire.

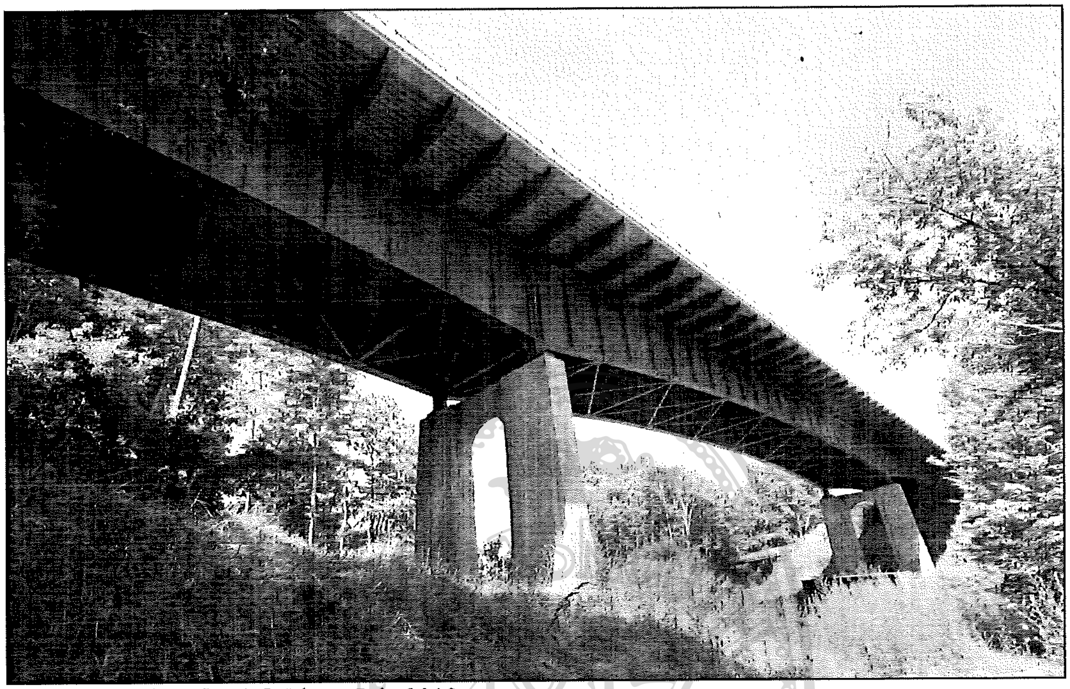
Photo copied from Movable and Long Span Steel Bridges, 1943. H.E. Langley, co-author, contributed the section on continuous bridges which included discussion and photo of the Sagamore Creek Bridge.



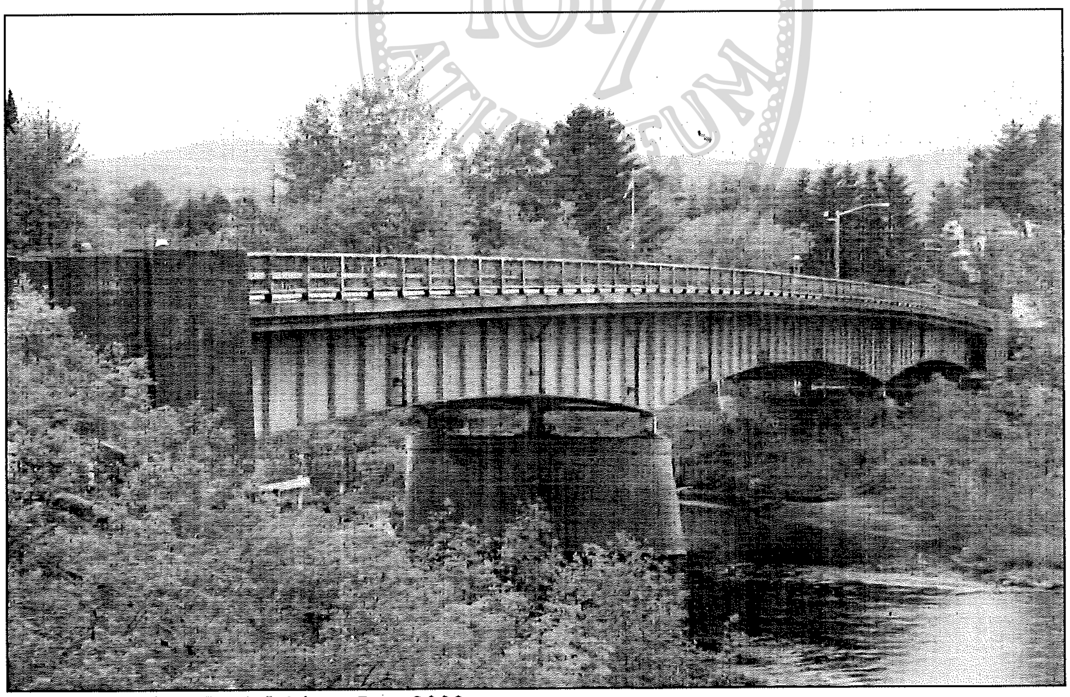
Conway 170/071 [1945]. Photo, June 1947, copied from Bridge Card.



Lebanon 077/107 [1945]. Photo, January 1946, copied from Bridge Card.



Lebanon 077/107 [1945]. Photo July 2010.



Stratford 029/206 [1947]. Photo June 2000.

PART II. ARCHITECTURAL INFORMATION

Sagamore Creek Bridge is a riveted steel three-span continuous deck plate-girder bridge on concrete abutments and piers. It carries US 1 in a north-south direction over Sagamore Creek, a tidal estuary that winds inland a distance of about 2 miles from its mouth at the Piscataqua River near New Castle. The creek narrows at the bridge to about 400', but wide tidal salt marshes extend over a thousand feet east and west of the bridge crossing. The area along US 1 north and south of the bridge is densely developed with a variety of uses, mostly commercial.

The bridge is 391'-2" in length overall, with a center span of 158'-1" and equal side spans of 116'-6", measured between the centers of the bearing pins. The girders are of the variable depth type, deeper at the ends than the center, the purpose being for both increased economy and aesthetics of design. The girders vary progressively in depth with the bottom flanges of the girders following the radius of a large curve and appearing in elevation as shallow arches. The center span has a horizontal clearance between piers of 144', a vertical clearance of 12'-6" above mean high tide and roughly 21'-2" above mean low tide.

The superstructure consists of the two plate girders spaced 19' on center. The girders are 7' deep at mid-span, 10'-6" at the piers and 8'-10" at the abutments. The bottom flange of the center span follows a radius of 790'-8" forming a shallow segmental arch. The two side spans follow a smaller radius of 535"-9" to maintain the same arch rise over the shorter span length. The plate girders are constructed with four 8"x8"x5/8" angles (two per flange) riveted to 5/8" web plates. A single full-length cover plate, 18"x7/8" is riveted to each flange. Vertical web stiffeners consisting of 6"x3-1/2"x3/8" angles fitted with 3-1/2" x 3/8" filler plates, are spaced 4'-2" apart along the full length of the girders. The web stiffeners align with the transverse floor beams above.

The girders are diagonally cross-braced (bottom lateral bracing) every 20 feet with 4"x3-1/2" angles of either 3/8", 1/2" or 7/16" thickness riveted to the bottom flanges. At the ends of the lateral bracing panels (every 20 feet) are "cross-frames" or sway braces, consisting of two angles riveted together to form a T-section joining the lower flange of the girders to the lower flange of the respective floor beam at its midpoint. A single angle vertical strut and double-angle lower lateral complete the sway brace frame. The connections on the cross frames are joined with gusset plates. The girders rest on cast steel bearings: six rocker-type expansion bearings at the piers and south abutment, and two fixed shoe-type bearings at the north abutment.

Floor beams are 21" deep wide flange beams with a weight of 62 pounds per linear foot (21WF62). These were installed in 1984 to replace visually identical but slightly lighter 21" wide flange beams with a weight of 59 pounds per foot (21WF59). The floor beams are spaced 4'-2" apart and aligned directly over the plate girder web stiffeners. The beams are of alternating lengths with the shorter beams carrying just the deck and the longer beams carrying the deck and the sidewalks. The shorter floor beams are 26'-4" in length and cantilever out 3'-2" beyond the outside of the plate girders. The longer beams (or sidewalk floor beams) are 33'-6"in length, cantilevering an additional 3'-2" beyond the short beams to carry the sidewalk. The projecting ends of the sidewalk floor beams are cut on a taper, decreasing in depth to 6" at the end of the beam.

The bridge is 33' wide overall, with a curb-to-curb roadway width of 26', two 3' sidewalks and two railings 6" in section. The bridge deck and sidewalks have open steel grid floors. According to the NHDOT Bridge Inventory Card the grid flooring is of the "I-beam Lok" type manufactured by Carnegie Steel. In this type of grid flooring the vertical flat bars of which it is constructed are tack-welded together to create a unified structural unit.

The roadway grid deck is 5" thick, with a grid opening of approximately 2"x4" and a specified weight of 20 pounds per square foot (p.s.f.). The grid flooring is welded to the floor beams. The sidewalk grid deck is 2" thick, with a maximum grid opening of approximately 1"x2" and a specified weight of 14 p.s.f. The sidewalk decks are 3' wide, raised 9" above the roadway, and welded to steel supporting angles and plates attached to the sidewalk floor beams. The curbs are steel angles welded to the sidewalk supports. Pipe conduits that originally carried telephone wires run under the east sidewalk through rectangular openings in the steel support plates.

The present bridge railing was installed in 1984 to replace the original railings which, plans indicate, were constructed of pipe posts and solid round bar vertical balusters. The present railing is 3'-6" high and consists of three rails of 4" square steel tubing welded to I-beam posts that are welded to the sidewalk supports and floor beams. The railings are anchored at their ends in concrete posts 4' x 2' in cross section that rise up from the sides of the abutment. The railing anchor posts are cast integral with the abutment, between the abutment facewall and the wings. The inside and outside of the posts are decorated with three vertical inset grooves or channels, each 6" wide by 2'-3" long. The center channel is 3" taller than the side channels; the channels taper in depth (like a ramp) from zero to 1-3/4" at the top.

The two reinforced concrete piers are constructed with two columns joined with a cap beam and footing. The footing is in two sections totaling 16' in height high and completely buried 2' or more below the stream bed. The lower footing section is rectangular, measuring 9' x 28' x 6' high. The upper footing section consists of two 7' square pedestals 10' in height, spaced on 19' centers to carry the pier columns. The pedestals are joined full height with a solid connecting wall 2' thick. The pier columns, also called pier shafts, consist of ½" thick wrought iron cylinders filled with reinforced concrete. The columns are 5' in diameter and 19' in height. Plans refer to the iron cylinders as "wrought-iron jackets," their primary purpose being the long term protection of the concrete inside from the deteriorating effects of seawater. The cylinders also served as "leave-in-place" form-work into which the concrete was poured, which offset some of the cost of the jackets, also referred to as armor. The pier cap measures 24'-8" long, 5'-8" wide and 3' high. The ends of the cap are half-rounded and overhang the pier columns by 4 inches.

The reinforced-concrete abutments are straight, with a solid back wall approximately 12' high with triangular wing walls (butterfly-type) extending about 14' to each side. Plans show the backwall seated on a buried open-type foundation 16' high, 16' x 30' at the base, with battered front and rear faces.

The bridge underwent a major rehabilitation in 1984, under Federal Project No. BHM-5379 (012) and State Project No. C-4059. In addition to the replacement of the floor beams and railing, mentioned above, work included replacing portions of the steel grid deck, replacing portions of the cross-frames and lateral bracing, repairing portions of the concrete abutment backwalls and wings, adding stone riprap fill in front of the abutments, cleaning and painting all structural steel, and replacing the approach guardrails.

Summary Structural Analysis of the Bridge and Stress Distribution to Key Bridge Components.

Prior to late 1940, the Sagamore Creek was crossed by a wooden trestle. This structure type is simple to construct of local materials consisting primarily of wood members and metal connections. The trestle is constructed of vertical wood piles driven into the soils below the water, creating piers (bents) transverse to the roadway alignment, spaced at a range 20' to 30', and then horizontally spanned by wood beams and deck. This structure is satisfactory for light vehicles, but does not provide a very wide span over the navigable channel, and the wood members deteriorate relatively quickly

The wood trestle bridge was replaced in 1941 with the 3-span steel deck plate girder bridge. The continuous span lengths were 116.5', 158.2', and 116.5'. Figure 1 shows the cross-section of the bridge structure. The two-lane driving surface was 26.33' wide, and made of open grid steel bars, which allowed rain and snow to drop through to the steel framing members and creek below. A narrow walkway was provided on each side, resulting in a bridge width of 33.5'.

Traffic loads were supported by the superstructure in the following load path:

- Traffic loads beared directly on the steel deck
- The steel deck spanned longitudinally to the steel floor beams
- The floor beams spanned transversely to the two main girders
- The two main girders spanned longitudinally between the piers and abutments.

This structural framing configuration makes efficient use of steel materials, because the numerous smaller floor beam and deck elements are supported by the two, deep, main girders. The variable depth girders were optimized by providing deeper webs at the pier supports, where the forces are highest. Saving steel was important during WWII, since steel was prioritized for the building of weapons. The indeterminate main girders, having variable depth and a continuous span arrangement, would be quite complicated to design without the aid of today's modern computers. The designers of the 1940's bridge likely used the principle of virtual work and Castigliano's theorem, which would require lengthy manual computations.

The two main girders were comprised of riveted elements consisting of a vertical web plate, double angle flanges, and cover plates on angle flanges. The steel was likely specified as ASTM A-7, with 33 kips/square-inch yield strength. A-7 steel has an uncontrolled carbon content is considered non-weldable due to its brittleness and resulting fatigue weakness. Thus the girder elements were riveted together, rather than welded. The ASTM A-7 specification was withdrawn in 1967, as steels with better properties became commonly available. The years of wet conditions resulted in the rusting and deterioration of the steel bridge members. Over the years, the design vehicles have become heavier, and the unmet needs to accommodate pedestrian and bicycle users of the bridge, had rendered the bridge obsolete by current standards, and the bridge was scheduled for replacement.

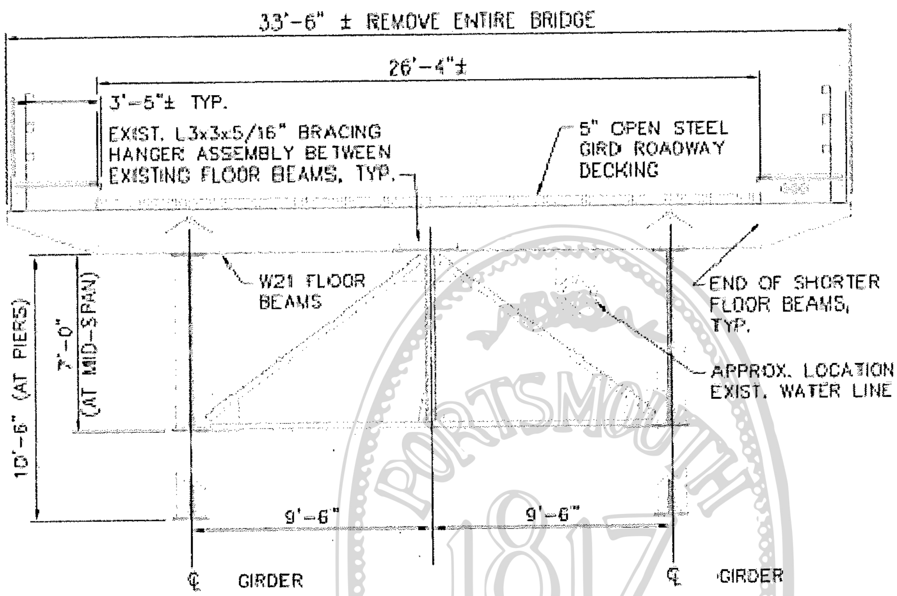


Figure 1, Steel Deck Plate Girder (1940's)

PART III. SOURCES OF INFORMATION

Anonymous
[Ca 1920] *Career of Hon. John Pender of Portsmouth, New Hampshire. Father of Ocean Boulevard.* (Brochure available at Portsmouth Athenaeum).

Anonymous
1935 Unsigned Draft Letter to the [NH] Governor and Council. Robert Marvin Collection [MS072} Box 1 Folder 4. Portsmouth Athenaeum

Bird, Harold Hughes
1920 *The Practical Design of Plate Girder Bridges.* Philadelphia: J.B. Lippincott.

Bishop, Carlton Thomas
1938 *Structural Design.* New York: John Wiley and Sons, Inc.

Bond, Emory and Gene E. Ellis
1960 "Vertical Clearance Without Center Pier" in *Welded Interstate Highway Bridges,* James D. Clark, editor. Cleveland, Ohio: James F. Lincoln Arc Welding Foundation.

Bowden, E. Warren.
1938 "Roadways on Bridges." *Engineering News-Record,* March 17, 1938, pp. 395-399.

Clark, James D. Clark, ed.
1960 *Welded Interstate Highway Bridge.* Cleveland, Ohio: James F. Lincoln Arc Welding Foundation.

Closs [Christopher] Planning Consultants
1985 Cohas Brook Bridge Historic American Engineering Record No. NH-9.

Closs [Christopher] Planning Consultants
1988 "Walpole-Westminster Bridge." Historic American Engineering Record No. NH-13.

Darnell, Victor
1984 "Directory of American Bridge-Building Companies 1840-1900." Society for Industrial Archeology Occasional Publication. No. 4 Washington, D.C.

Densford, Thomas [Fay, Spofford & Thorndike]
2015 Memorandum of Summary Structural Analysis

Engineering News
1891"Plate Girder Highway Bridge: Brookline, Mass." (September 19, 1891), p. 257.
1892"The State Street Plate Girder Bridge." 27 (February 27, 1892), p. 205.
1900 "Plate Girder Park Foot Bridge at Madison, N.J." 44 (August 23, 1900), p. 134.

Engineering News-Record
1937 "Bridge Floor Development," July 15, 1937, p. 90.

Engineering Record
1895 "The Spring Avenue Bridge, Troy, N.Y." 32 (November 30, 1895), pp. 471-472.
1900A"The Wellsville Over-Grade Bridge." 42 (August 4, 1900), p. 101.
1900B "A Plate Girder Bridge with Concrete Floor." 42 (October 6, 1900), p. 323.
1905A"The Highway Bridge over the Wabash River at Terre Haute." 51 (June 17, 1905), pp. 672-675.
1905B"Replacing a Howe Truss Span with Plate Girders." 51 (June 17, 1905), p. 681
1910A "County Highway Bridges." 61 (January 22, 1910), pp. 89-90.
1910B"Highway Bridges in Illinois." 61 (March 19, 1910), p. 318.
1910C "A 109 Ft. Concrete-Floor Plate Girder Bridge." 61 (May 21, 1910), pp. 662-663.

Feldman, Earl
1931 "Principles of Design of Steel Highway Bridges." In *Public Works* 62 (May, 1931, pp. 26, 89, 90; June, 1931, pp. 48, 68).

Fuller, Almon H. and Frank Kerekes
1936 *Analysis and Design of Steel Structures.* New York: D. Van Nostrand Company, Inc.

Garvin, James L.
1999A "Builders of Bridges in New Hampshire," uncompleted MSS, available from the author.

Garvin, James L.
1999B "Bridges of the Piscataqua," typescript on file at the New Hampshire Division of Historical Resources, Concord.

Garvin, James
2000-A "Engineers known to have worked in bridge design at the New Hampshire Highway Department from the 1920s to the 1940s," MSS Available from the author.

Garvin, James L.,
2000B "Bridge Book, Volume 2, January 2000 Draft." Unpublished draft manuscript available from the author, New Hampshire Division of Historic Resources,

Garvin, James L.
2004 "New Hampshire Good Roads Projects, 1904-2004," New Hampshire Division of Historical Resources, Concord.

Gurney, Caleb Stevens
1902 Portsmouth, Historic and Picturesque: a Volume of Information. Portland ME: Lakeside Press.

Hammond, Isaac
1884 Documents Relating to Towns in New Hampshire (New London to Wolfboro). Concord: Parson Cogswell.

Harger, Wilson G. and Bonney, Edmund A.
1927 *Handbook for Highway Engineers.* New York: McGraw-Hill Book Company, Inc.

Hews, Laurence I.
1942 *American Highway Practice*. New York: John Wiley and Sons, Inc.,

Hill, Albert F.
1882 "Riveted Girders" *Engineering News* (April 8, 1882), p. 109.

Houk, H.H.
1935 "Developments in Highway Bridge Design," *Civil Engineering* (December 1935), pp. 763-767.

Howe, Malverd A.
1906 "The Wabash River Bridge at Terre Haute, Indiana," *Engineering News* 55 (March 8, 1906), pp. 273-275.

Johnson, J. B., C. W. Bryan, & F. E. Turneaure
1906 . *Theory and Practice of Modern Framed Structures.* [2nd Edition] New York: John Wiley and Sons.

Ketchum, Milo S.
1908, 1920 *The Design of Highway Bridges of Steel, Timber and Concrete.* New York: McGraw-Hill Book Co. [first edition 1908, second edition, 1920].

Kunz, F.C
1915 *Design of Steel Bridges.* New York: McGraw-Hill Book Company.

Lamb, George W.
1935 "Continuous Spans Favored for Kansas Highways," *Engineering News-Record* (November 21, 1935), pp. 702-705.

Louis Berger Group 2000
"Newfields-Stratham Swing Bridge." Historic American Engineering Record.

Lindenthal, Gustav
1932 "Bridges With Continuous Girders," *Civil Engineering* (July 1932):421;

McCullough, Conde B.
1929 *Economics of Highway Bridge Types*. Chicago: Gillette Publishing Company.

Merriman, Mansfield and Henry S. Jacoby.
1894 *A Text-Book on Roofs and Bridges, Part 3.* New York: John Wiley and Sons.

New Hampshire Highways
1928 "Flood Emergency Bridges" (June, 1928), n.p.

New Hampshire State Highway Department
1927 Fourth Annual Report of the State Highway Department of New Hampshire (Concord).

New Hampshire State Planning and Development Commission
1942 A Plan for Development of the Seacoast Region of New Hampshire

Moore, John W. ?
Ca. 1988A "Bridge Building in New Hampshire, An Historic Overview." Anonymous typewritten manuscript in "Historic Bridge Survey" binders shelved in the Bridge Section, NHDOT. Presumed written about 1988 by John W. Moore, a NHDOT bridge engineer.)
Ca. 1988B "John William Storrs/Storrs and Storrs, Concord, New Hampshire." Anonymous typewritten manuscript located in "Historic Bridge Survey" binders shelved in the Bridge Section, NHDOT. Presumed written about 1988.

Ogden, C.W.
1937 "The Modern Trend in Bridge Design," *Civil Engineering* (June 1937):402-405.

Parsons Brinkerhoff Quade & Douglas, Inc.
1997 *Small Structures on Maryland's Roadways.* Prepared for Maryland State Highway Administration, Baltimore, Maryland.

Portsmouth Herald
1910 "Sagamore Creek Bridge." 14 Mar. 1910.
1920 "Making Repairs on Sagamore Bridge." 19 Nov. 1920.
1922 "Some History of Present Bridge over the Sagamore Creek" 13 May 1922:
1922 "Council May Build New Bridge at Sagamore." 15 Dec. 1922: n. pag.
1922 "Council to Issue Bonds to Rebuild Sagamore Bridge." 22 May 1922: 8. .

1923 "To make Repairs on the Bridge." 7 Apr. 1923: n. pag.
1934 "Tells of Changes in Fifty Years." 10 January 1934: 8
1938 "Seacoast Association Meeting at Durham." 4 Feb. 1938: 1,5
1938 "Summer Meeting of Seacoast Association on June 6." 1 June 1938: 12.
1938 "Sagamore Bridge." 29 Aug. 1938.
1940 "Long Range Planning Program Projected." 13 June 1940: 1,2.
1940 "Favor New Location for Sagamore Bridge." 15 Aug. 1940: 1.
1940 "New Bridge to be Built at Sagamore Creek." 24 Aug. 1940: 1
1940 "Sagamore Creek Bridge Hearing Set Next Week." 23 Sept. 1940..
1940 "Work on New Sagamore Creek Bridge to Start." 6 Dec. 1940: 1.
1940 "Sagamore Bridge Construction Starts." 26 Dec. 1940: t.
1941 "Sagamore Bridge." 20 May 1941..
1941 "New Bridge Opened Quietly Yesterday." 7 July 1941: 3
1941 "Portsmouth's $14 Million Defense Projects." 8 July 1941
1942 "F.P. Clark St. Planning Director Resigns" February, 14, 1942
1961 Harold Langley Retires. September 22, 1961: 14.

Portsmouth Journal
1850 "Sagamore Bridge" 3 August 1850
1850 "Sagamore Bridge" 21 September 1850:Np

Portsmouth Scrapbook, Portsmouth Public Library. Volumes for 1938-41.

Preservation Company
1996 "Water Street Bridge." Historic American Engineering Record No. NH-29.
2009A Historic Structures Report Memorial Bridge.
2009B NHDHR Individual Inventory form for Maine-New Hampshire Interstate Bridge/Sarah Mildred Long Bridge.

Richart, F.E., N.M. Newman, and C.P. Siess.
1949 "Highway Bridge Floors, A Symposium." (Paper No 2381). American Society of Civil Engineers Transactions, 114 (1949):979-1072.

Skinner, Frank W.
1906 *Types and Details of Bridge Construction.* New York: McGraw-Hill Publishing Company.

Smith, E.D.
1939 "Building a Beautiful Bridge," *Engineering News-Record* (December 21, 1939):59-61.

U.S. Army Corps of Engineers [USACE] St. Louis District
1997 Archives Search Report… Fort Dearborn. Accessed online http://naelibrary.nae.usace.army.mil/dp194/nae97057.pdf

Waddell, J.A.L.
1916 *Bridge Engineering.* New York: John Wiley and Sons,
1921 *Economics of Bridgework.* New York: John Wiley and Sons.
1927 "Suitability of the Various Types of Bridges for the Different Conditions Encountered at Crossings. *Journal of the Western Society of Engineers* 32 (October 1927).
1938 "Economics of Highway Bridge Flooring of Various Unit Weights." *American Society of Civil Engineers Transactions,* 103 (1938):515-550.

Warren, William H.
1894 *Engineering Construction in Iron, Steel and Timber.* New York: Longman Greens & Co.

Wells, Melville B.
1913 *Steel Bridge Designing.* Chicago: The Myron C. Clark Publishing Company.

Wysong, Jack
1997 The World, Portsmouth & the 22nd Coast Artillery. Missoula, Mt: Pictorial Histories Publishing Company.

Xanthakos, Petros P.
1996 *Bridge Strengthening and Rehabilitation.* Upper Saddle River, NJ: Prentice Hall.

Maps
Sanborn Map and Publishing Company
1939, 1956 (revised), 1970 (revised).
Portsmouth, New Hampshire. New York: Sanborn Map and Publishing Co. Microfilm Collection New Hampshire Historical Society.

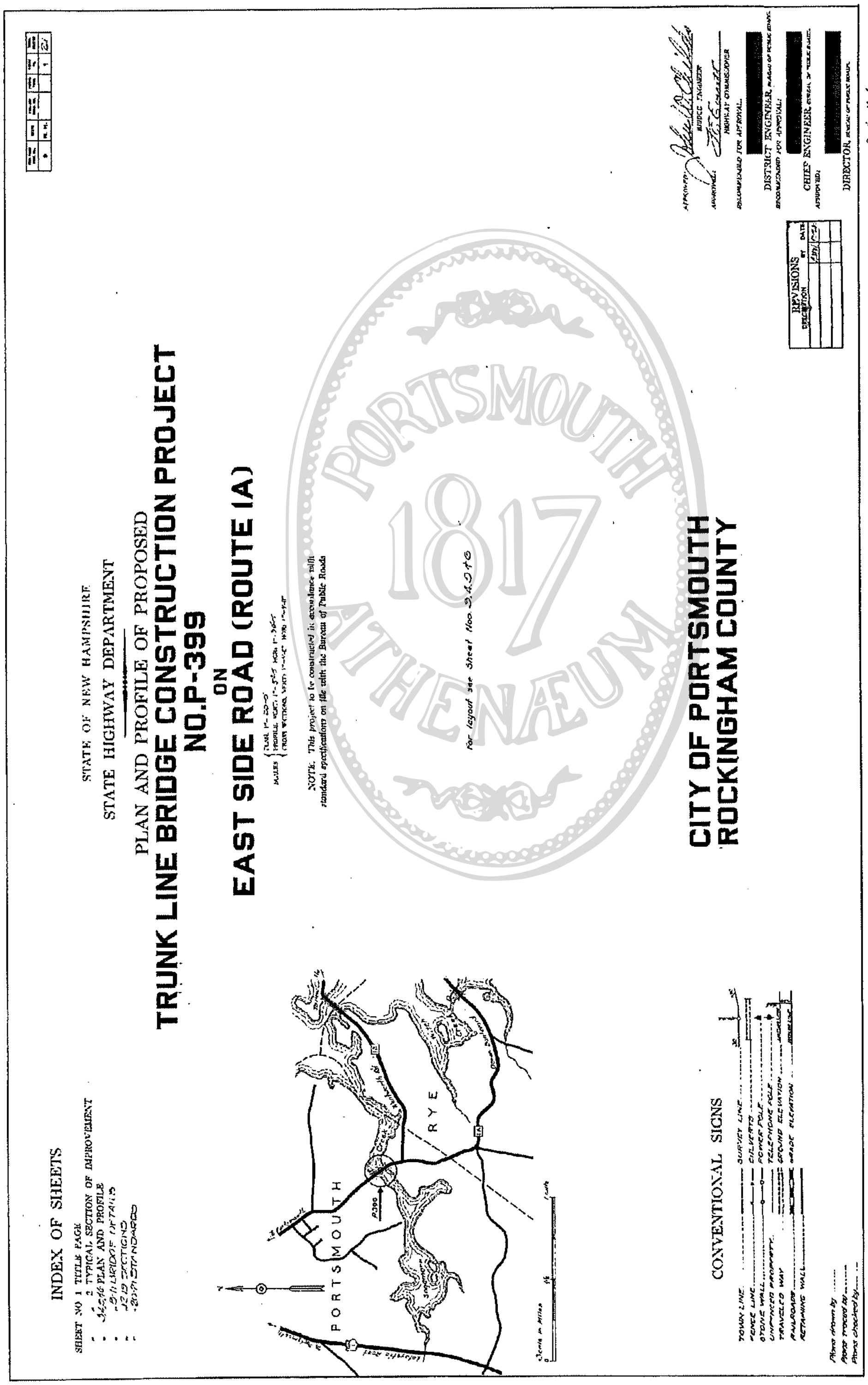
Plans
New Hampshire Department of Transportation,
1940 *et seq* Plans files. "PWA Project No. NH 1037-F/Maine 1088-F" (1940) and subsequent plans for alterations.

Historic Photographs
Portsmouth Athenaeum files
Thayer Cumings Library, Strawbery Banke Museum

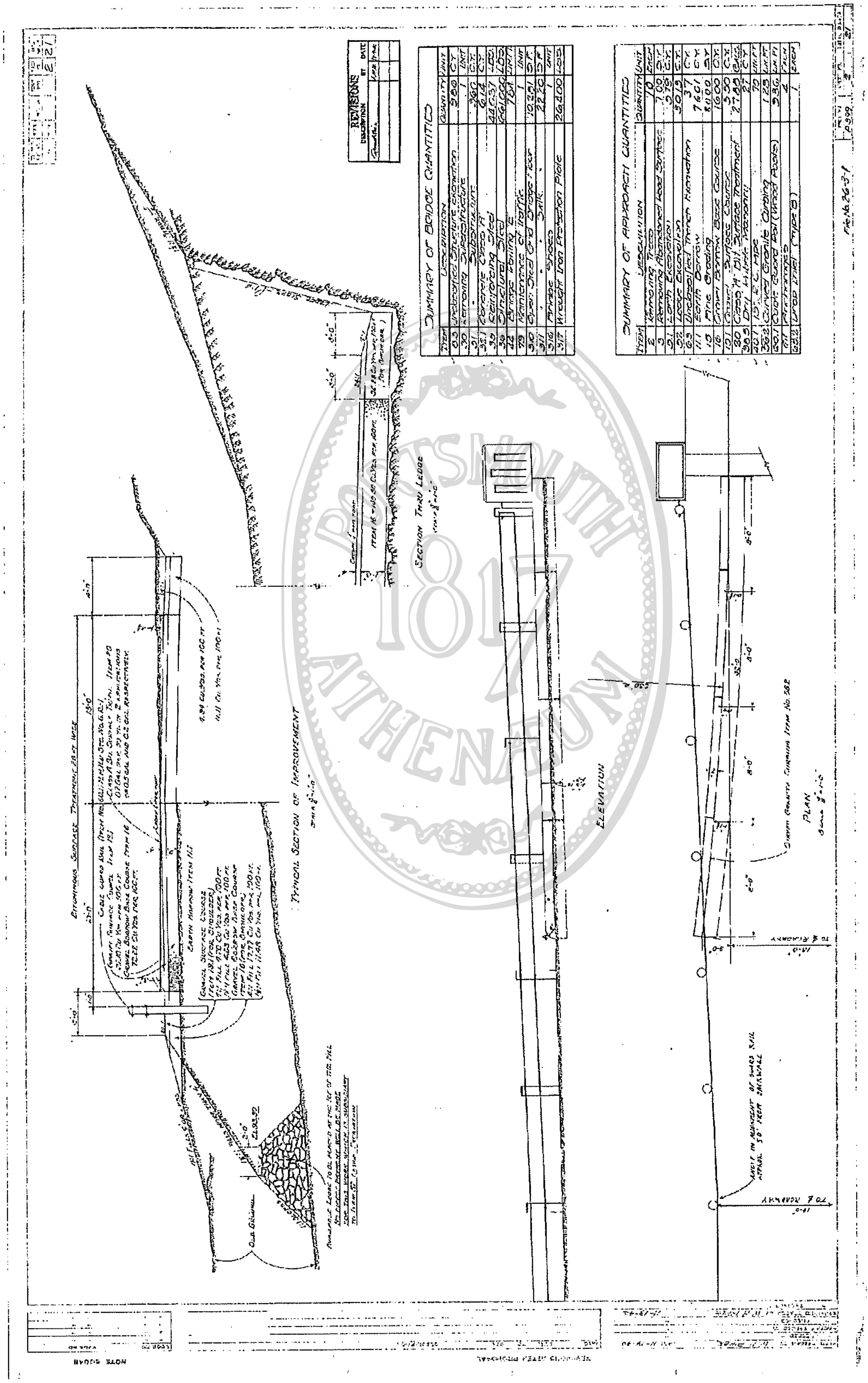
MEASURED DRAWINGS

Sagamore Avenue Bridge, Route 1A
Portsmouth
Rockingham County
New Hampshire

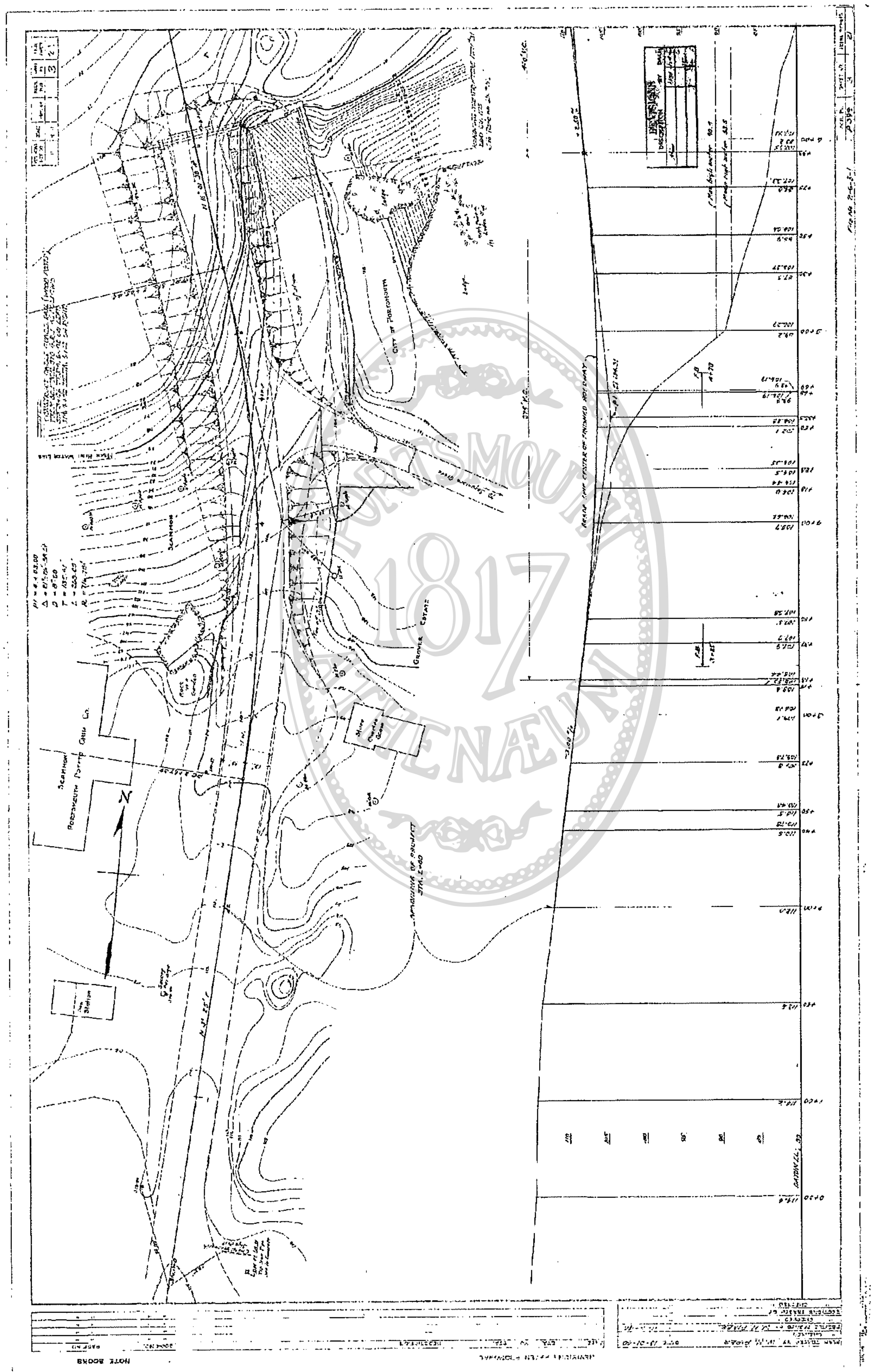
NH STATE NO. 713



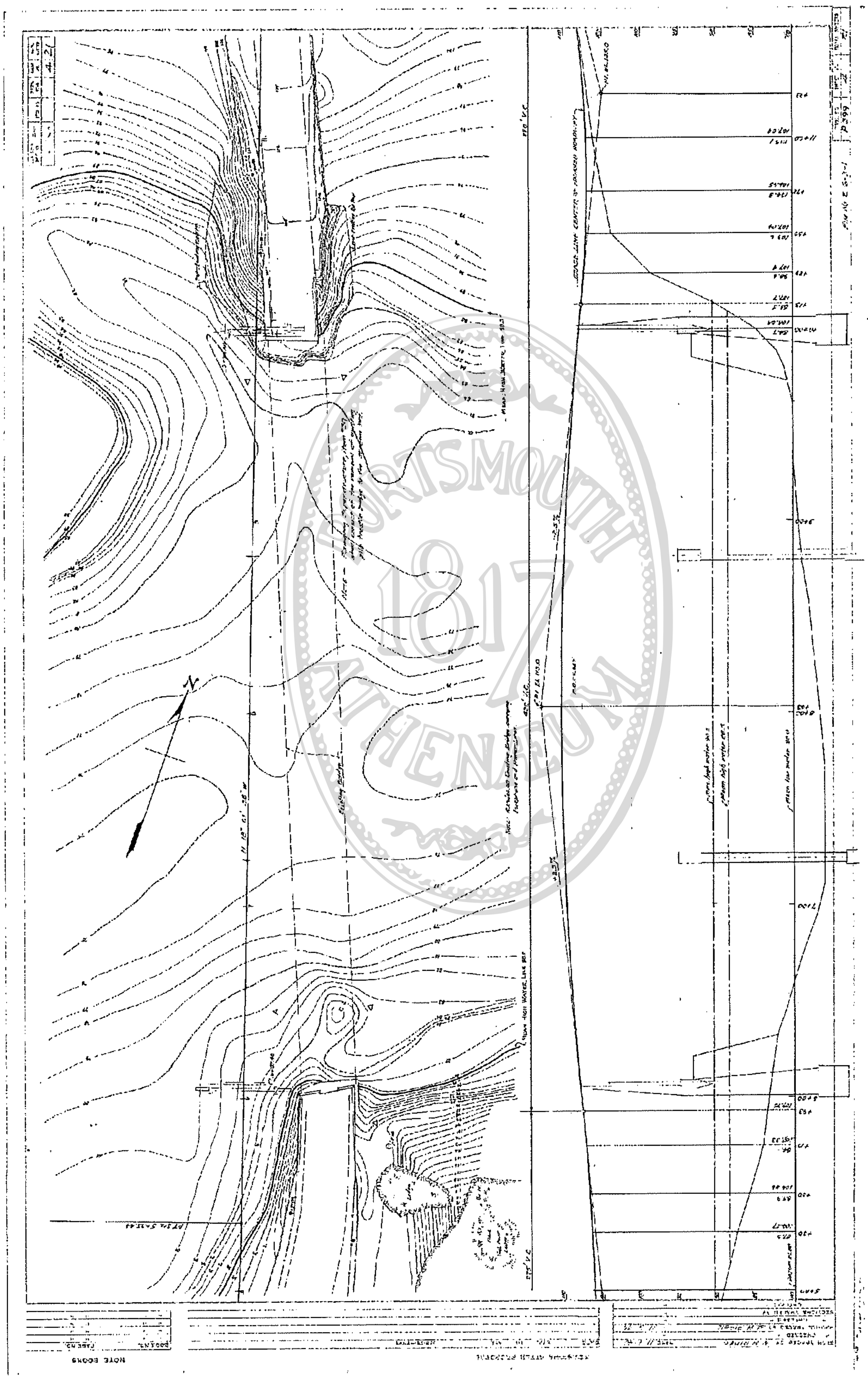
MEASURED DRAWINGS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 2)

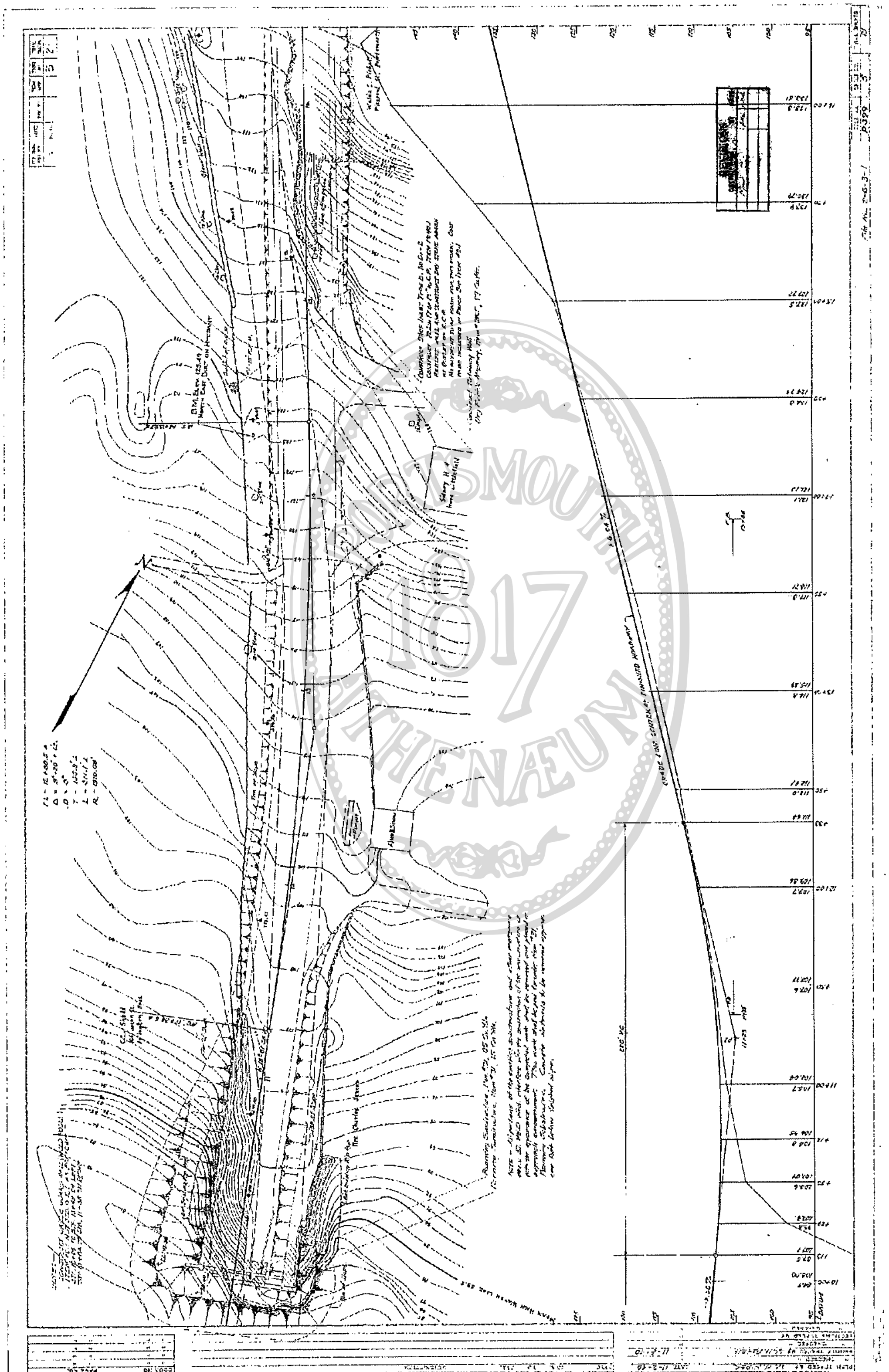


MEASURED DRAWINGS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 3)

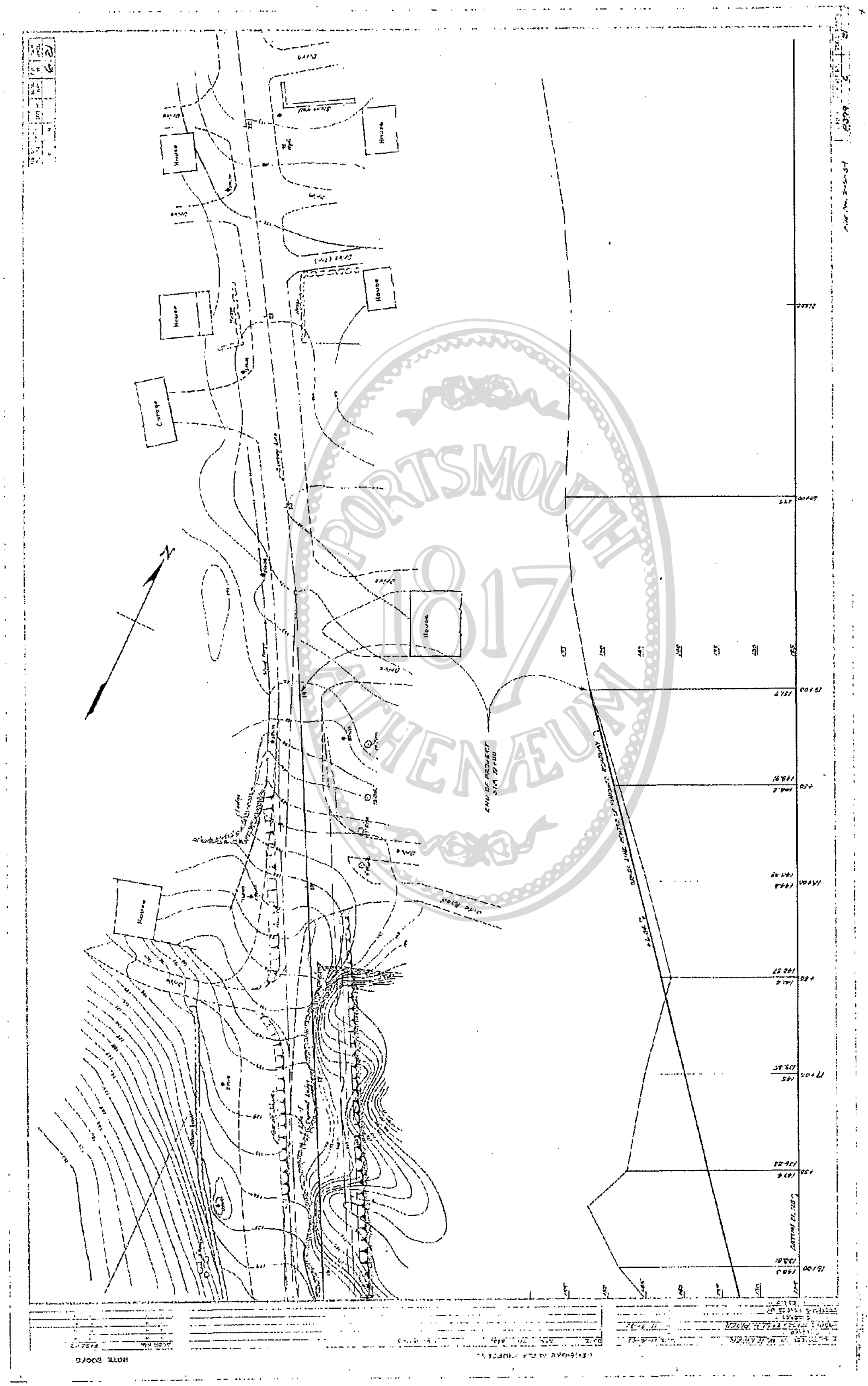


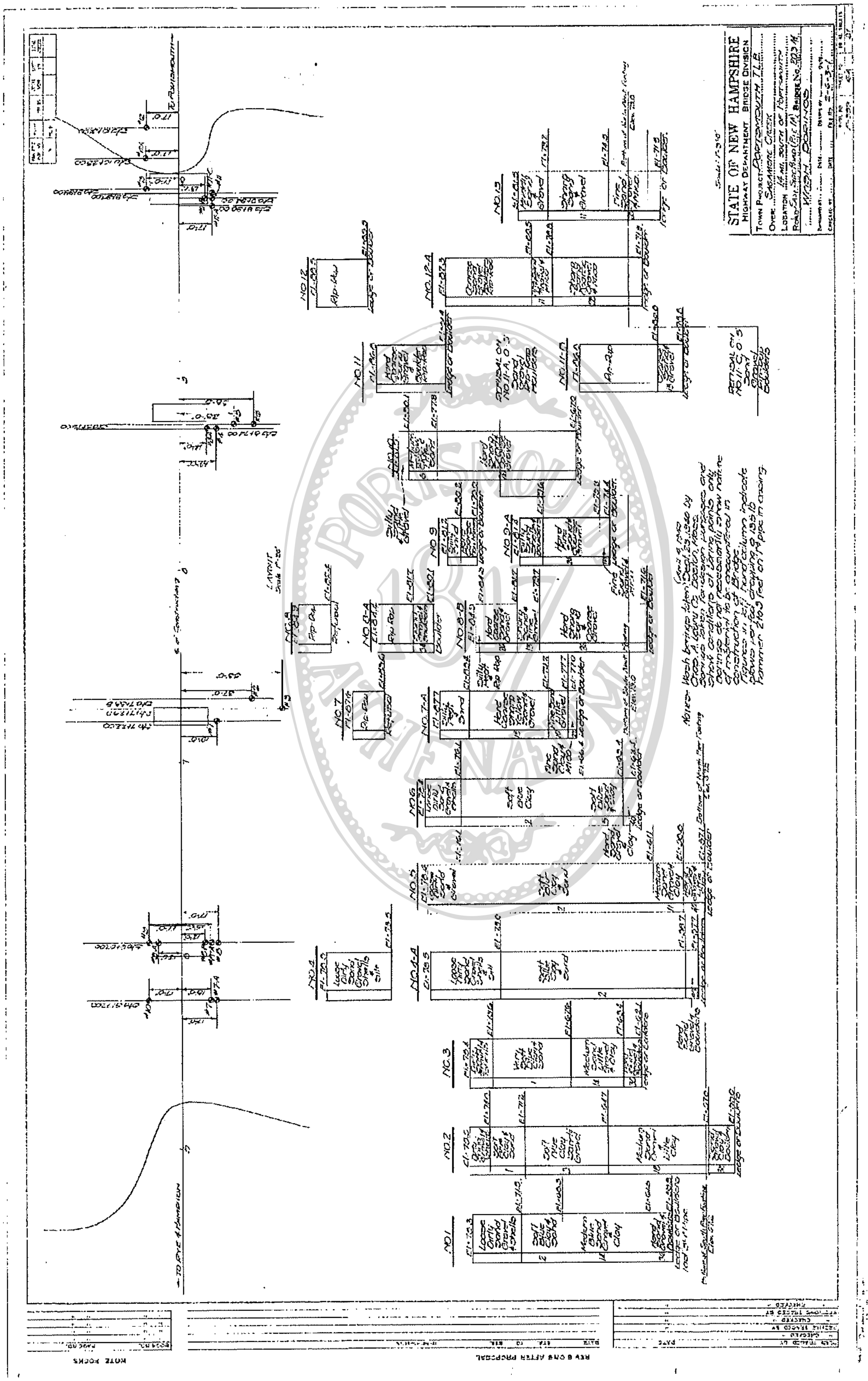
MEASURED DRAWINGS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 4)



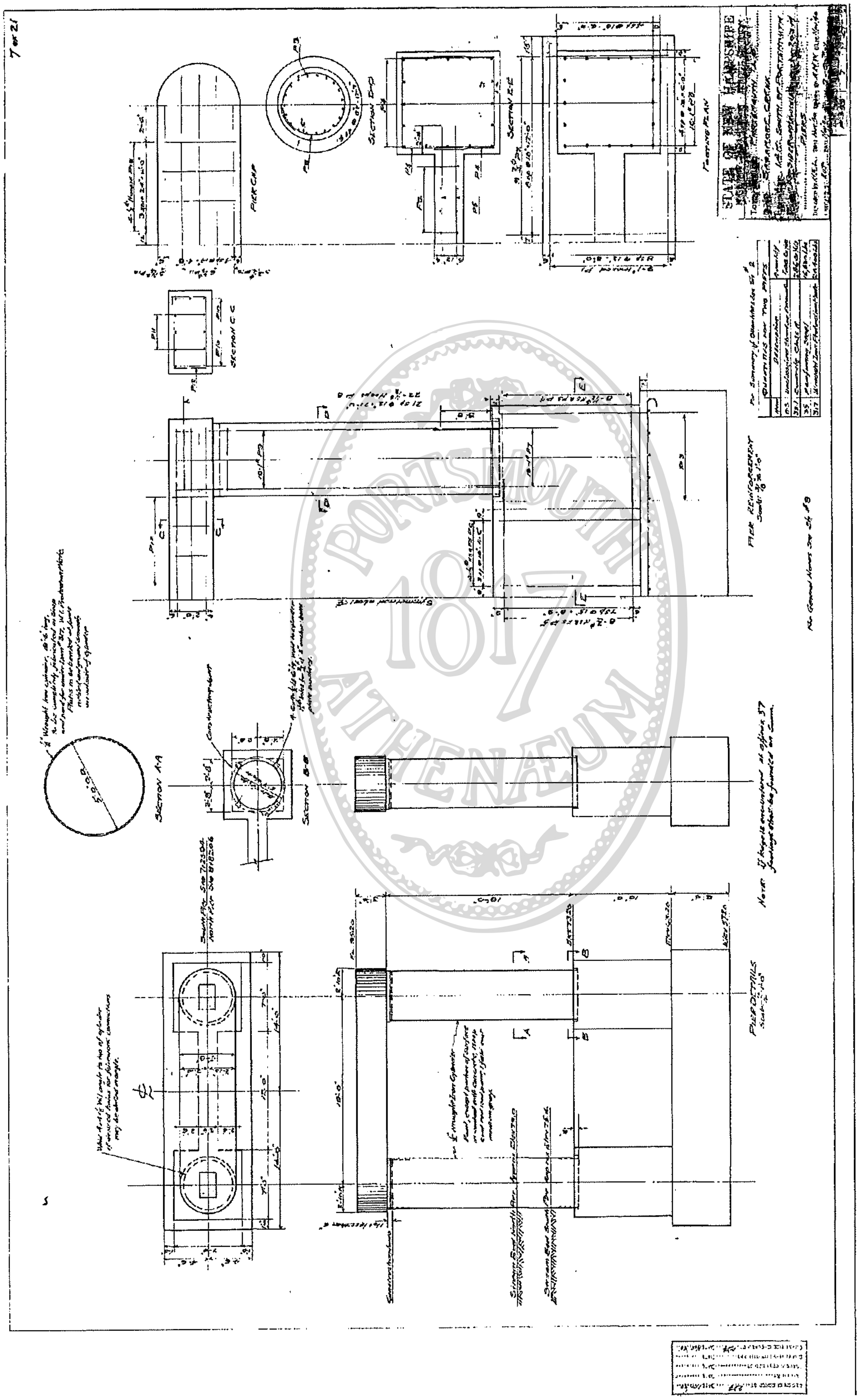


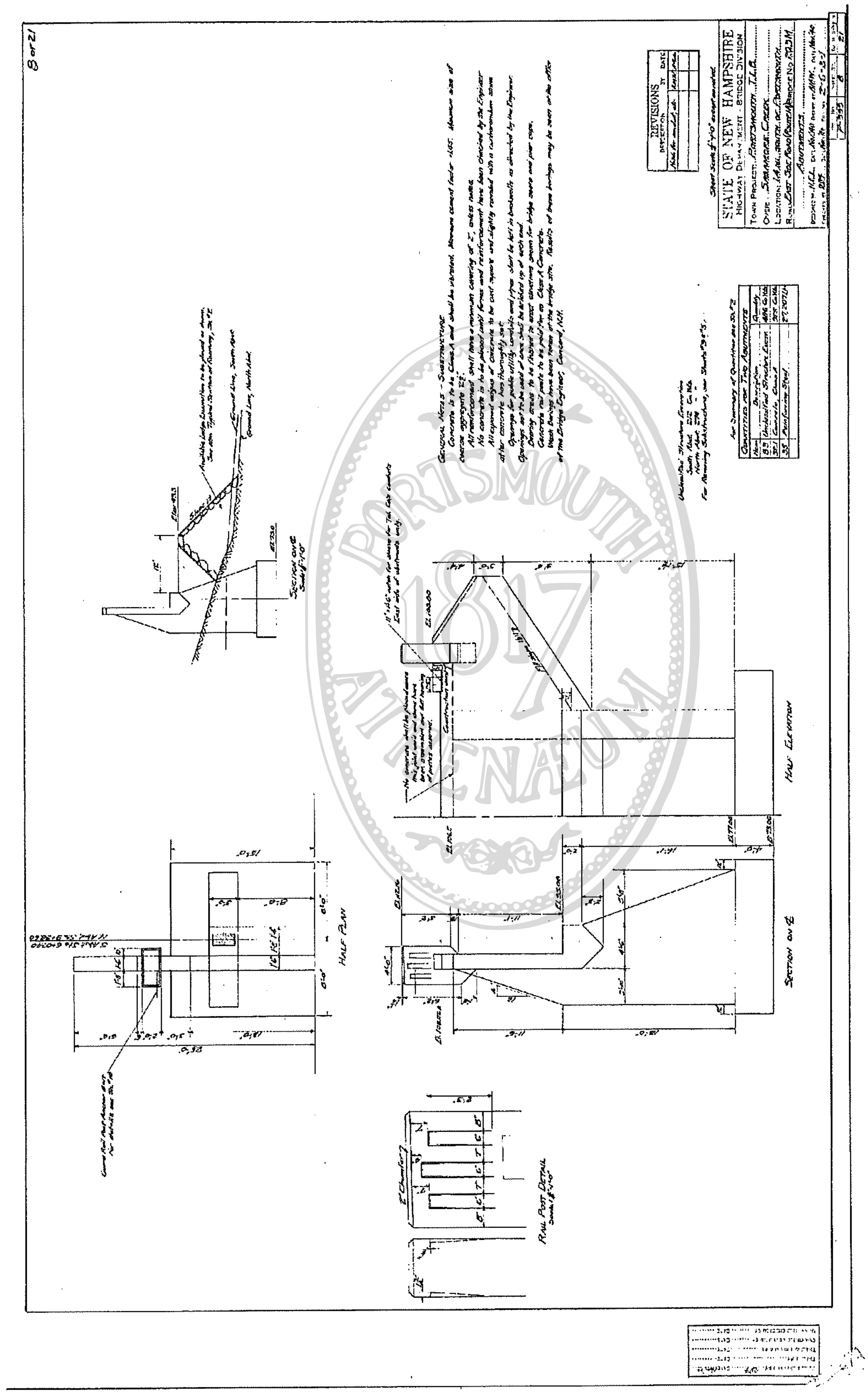
MEASURED DRAWINGS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 6)





MEASURED DRAWINGS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 8)

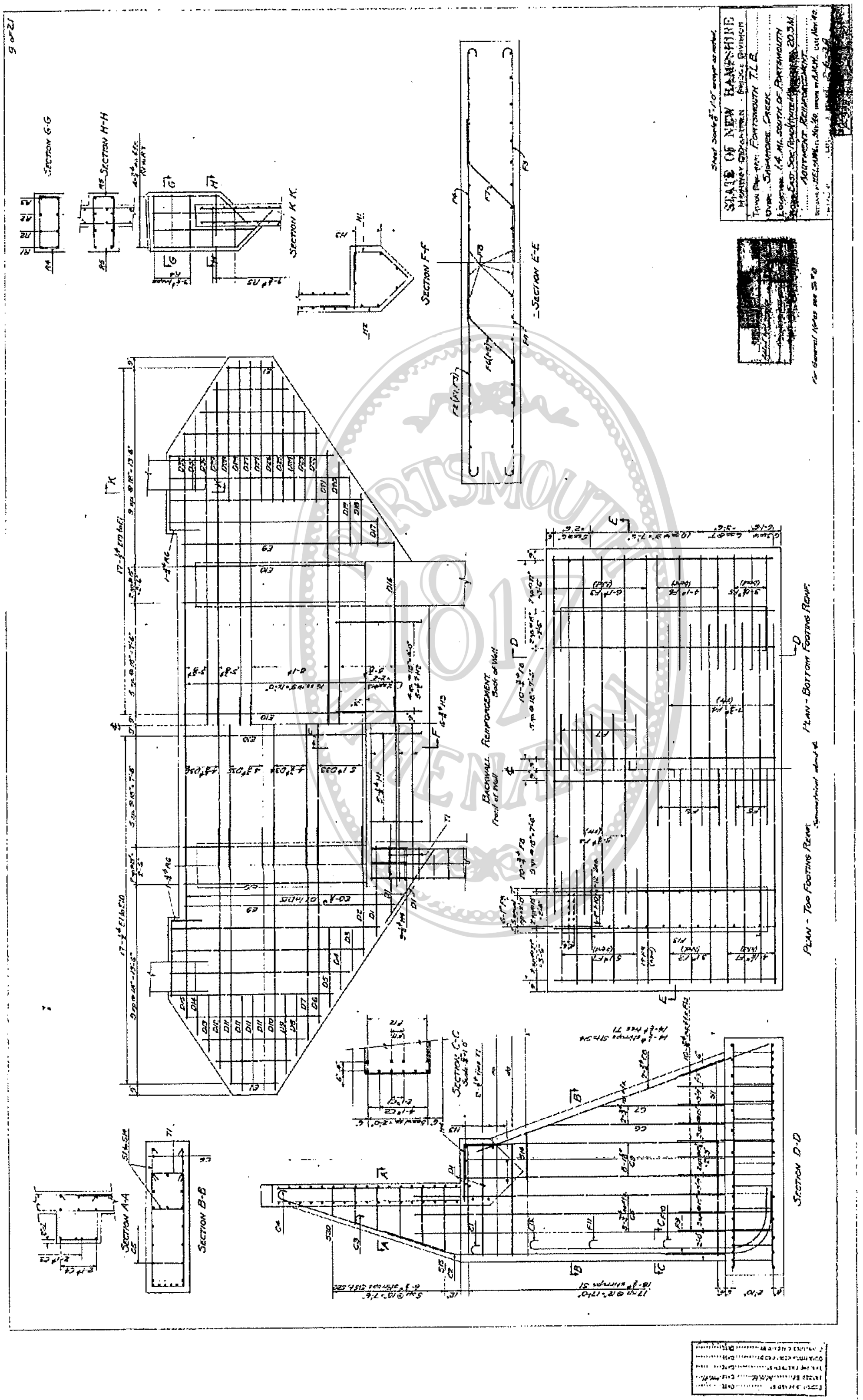


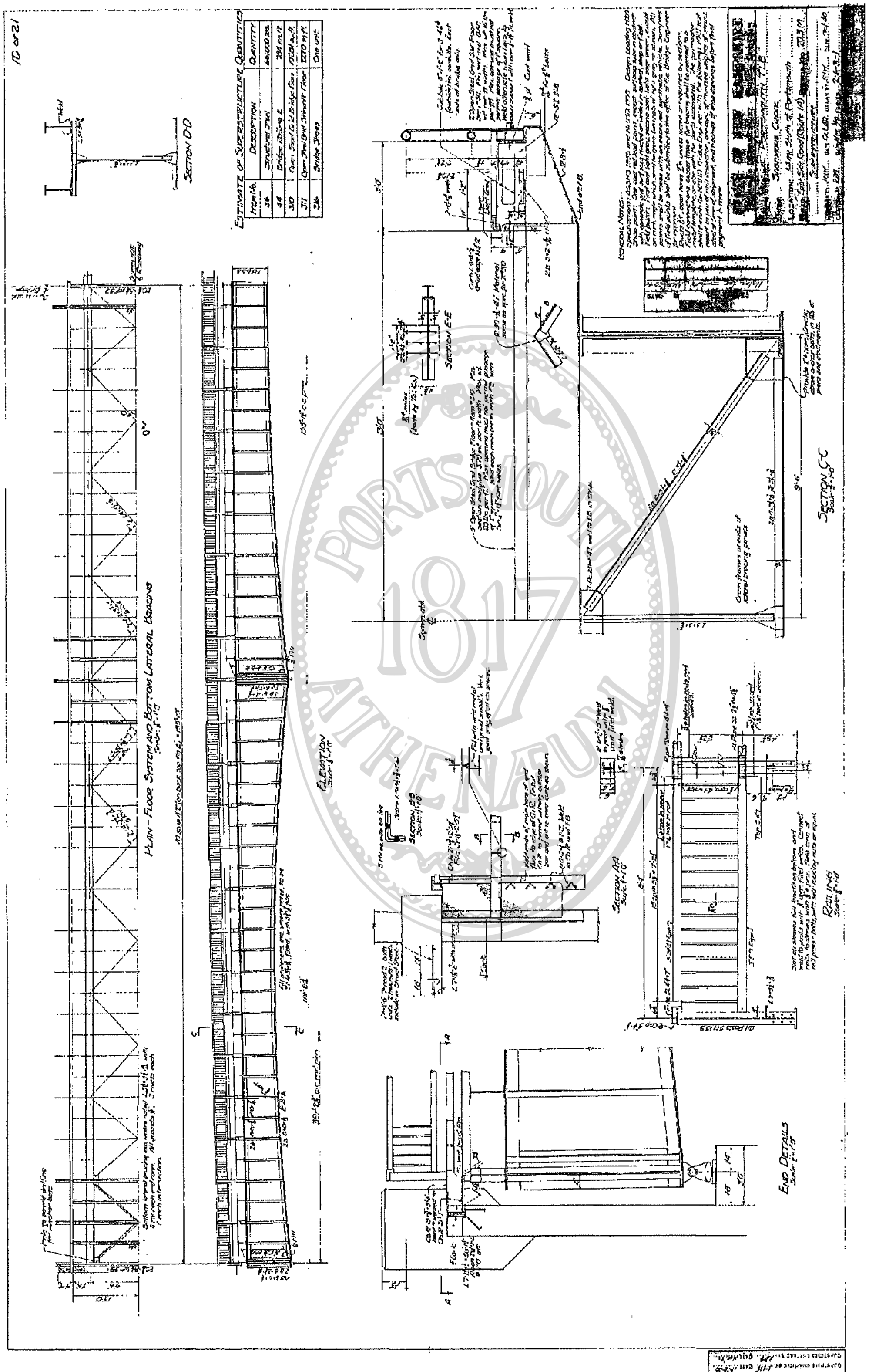

STATE OF NEW HAMPSHIRE
REVISIONS
HALF PLAN
SECTION ON ℄
HALF ELEVATION
RAIL POST DETAIL
8 OF 21

MEASURED DRAWINGS

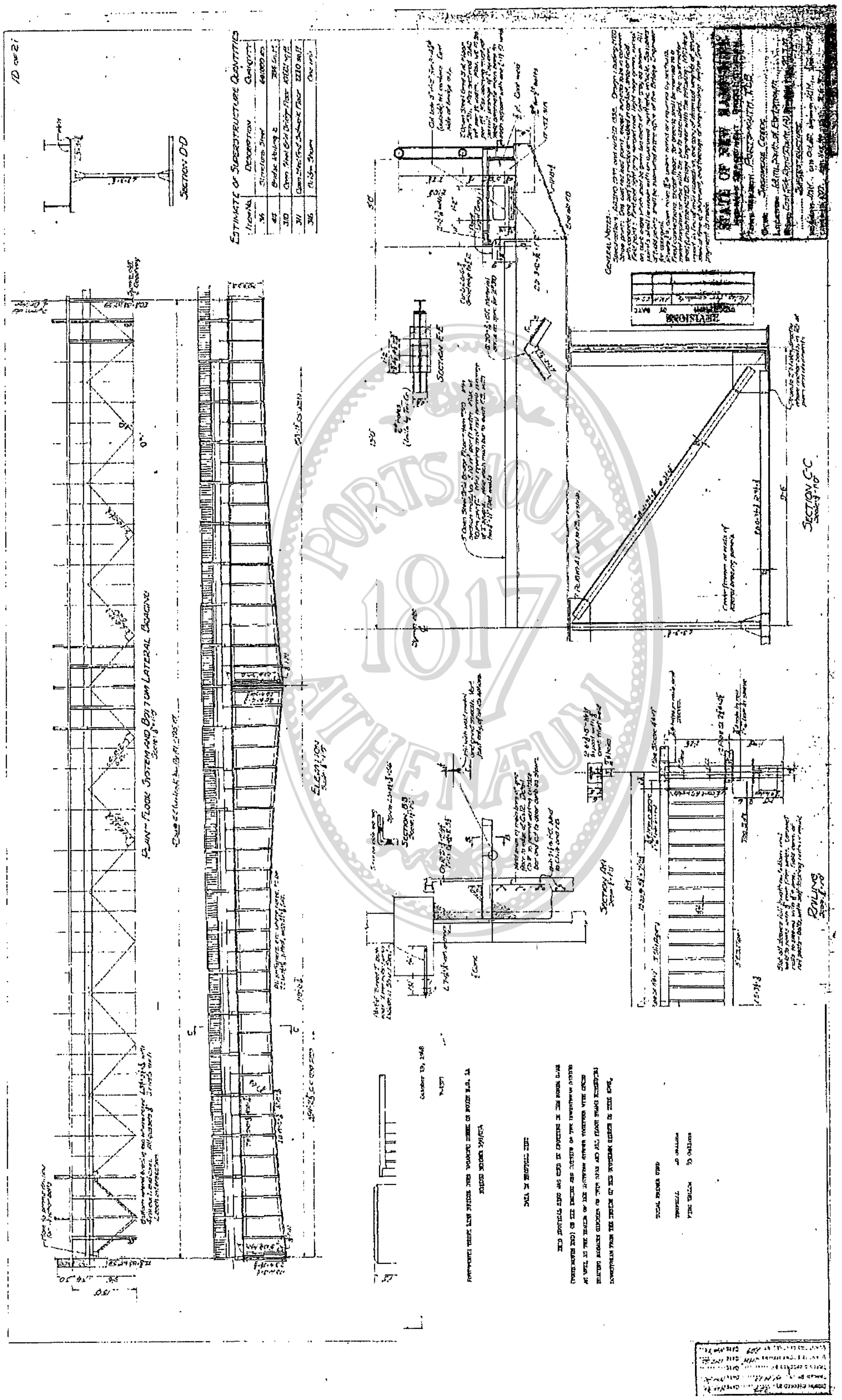
Sagamore Avenue Bridge, Route 1A

NH STATE NO. 713 (Page 10)

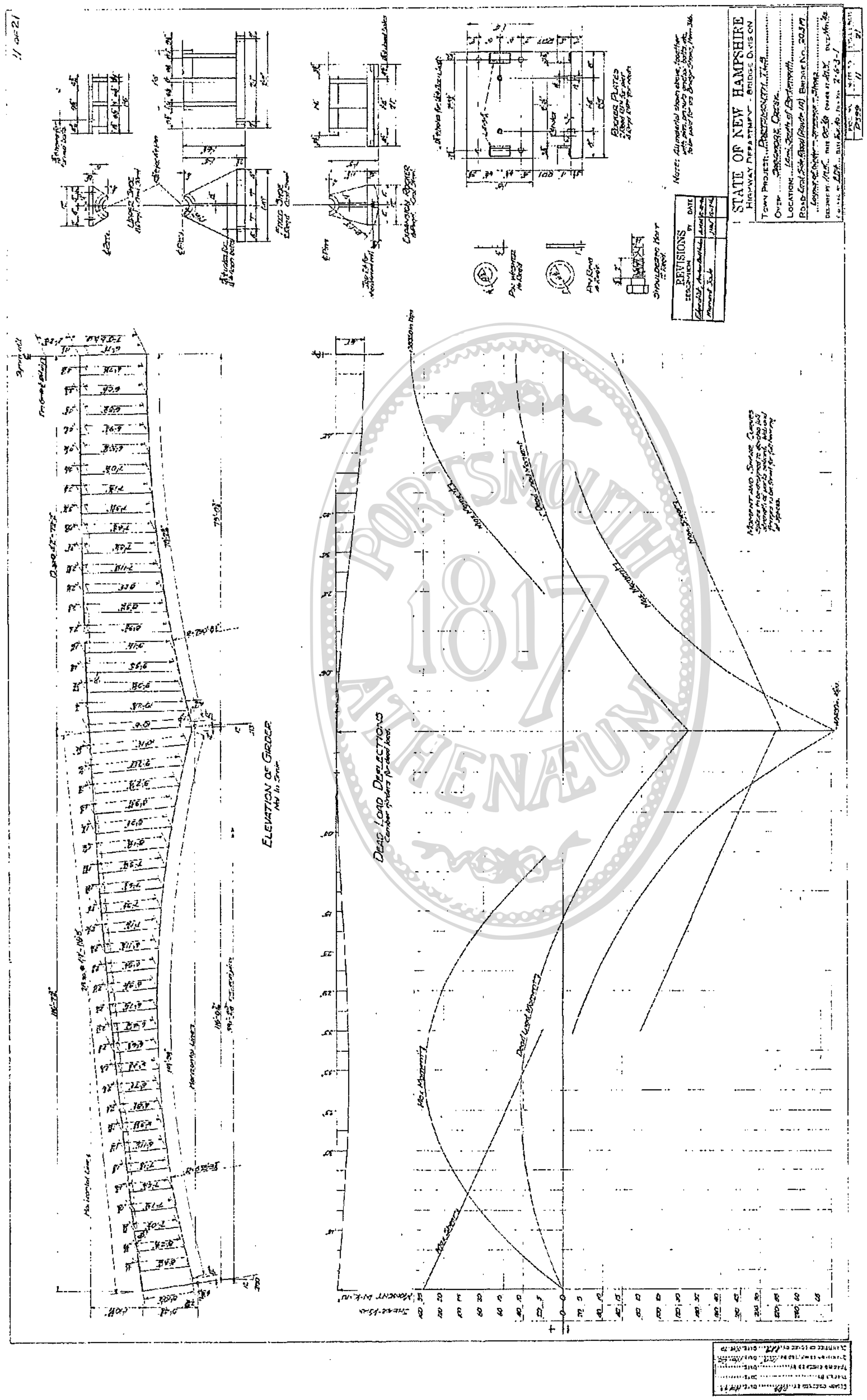




MEASURED DRAWINGS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 12)



MEASURED DRAWINGS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 13)



INDEX TO PHOTOGRAPHS

Sagamore Avenue Bridge, Route 1A
Portsmouth
Rockingham County
New Hampshire

NH STATE NO. 713

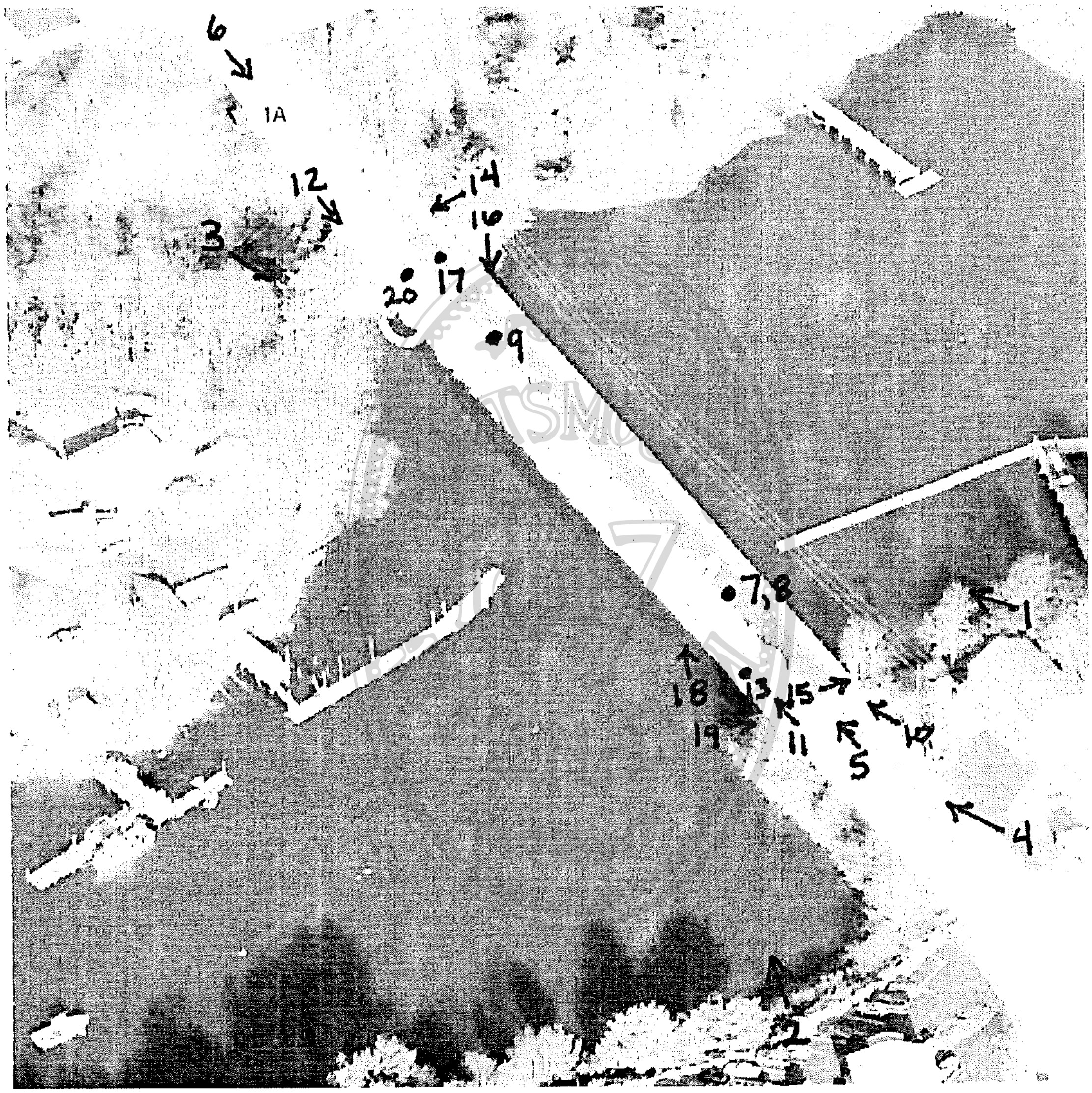
Photographer: Charley Freiberg, Elkins, NH, for Preservation Company, April 15, 2013.

Number	View Looking	Showing
Overview		
1.	NW	Downriver elevation of the bridge from the south
2.	N	Upriver elevation of the bridge from the south
3.	SE	Upriver elevation of the bridge from the north
4.	NW	South bridge approach
5.	NW	South bridge approach
6.	SE	North bridge approach
7.	NW	Underside of bridge from the south
8.	NW	Underside of bridge from the south
9.	SE	Underside of bridge from the north
Superstructure		
10.	NW	South bridge approach, pavement meeting steel grid deck/sidewalk, downriver side
11.	N	South bridge approach, pavement meeting steel grid deck/sidewalk, upriver side
12.	SE	North bridge approach, pavement meeting steel grid deck/sidewalk
13.	N	Steel grid deck/sidewalk from below, upriver side from the south
14.	SW	Northeast abutment, outer side, Art Deco detail
15.	NE	Southeast abutment, inner side, Art Deco detail and guardrail
16.	S	Steel girder, plates, and rivets on downriver elevation, from the north
17.	S	Lateral steel bracing between girders
Substructure		
18.	N	Piers from the south
Abutments		
19.	SE	South abutment, upriver side
20.	NE	North abutment, beneath decking

KEY TO PHOTOGRAPHS

Sagamore Avenue Bridge, Route 1A
Portsmouth
Rockingham County
New Hampshire

NH STATE NO. 713



REFERENCE PHOTOGRAPHS

Sagamore Avenue Bridge, Route 1A
Portsmouth
Rockingham County
New Hampshire

NH STATE NO. 713

Photographer: Charley Freiberg, Elkins, NH, for Preservation Company, April 15, 2013.

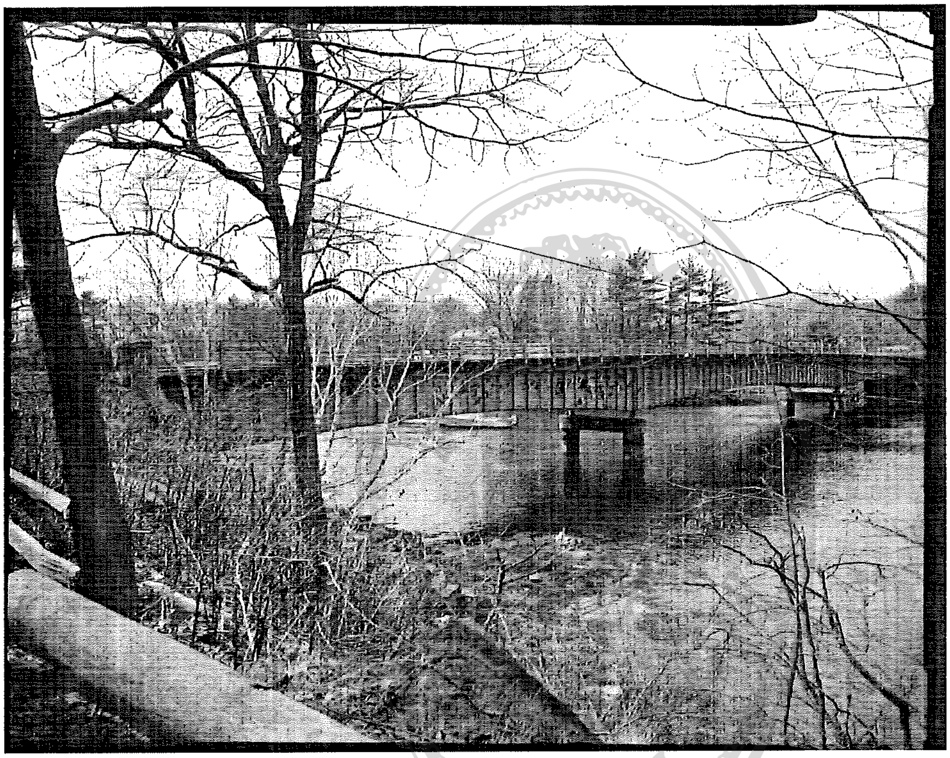


Photo 1.

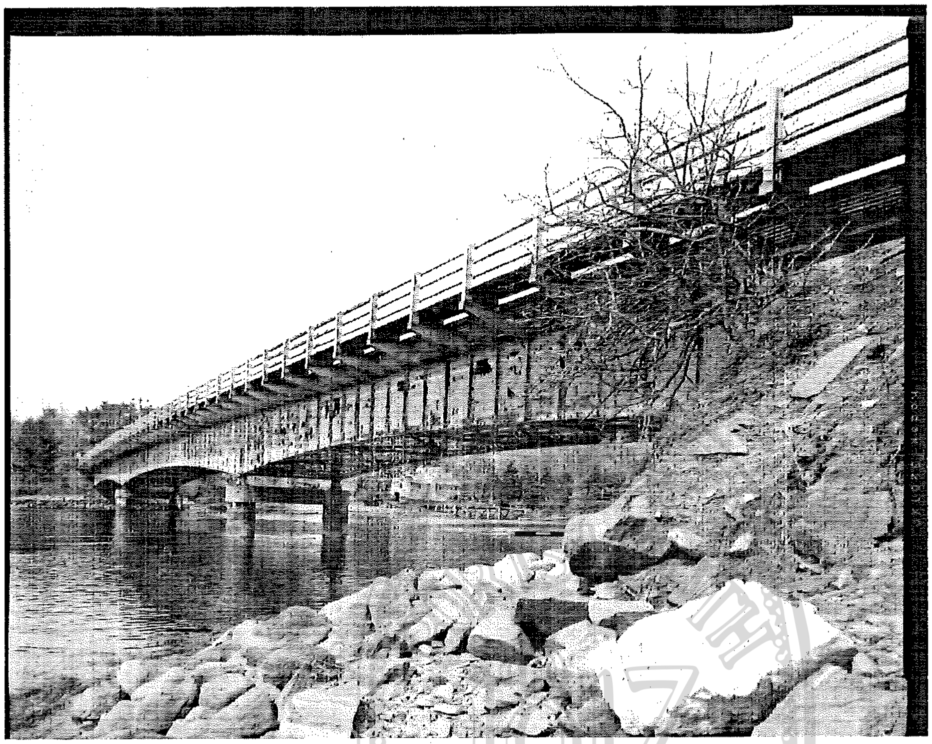


Photo 2.

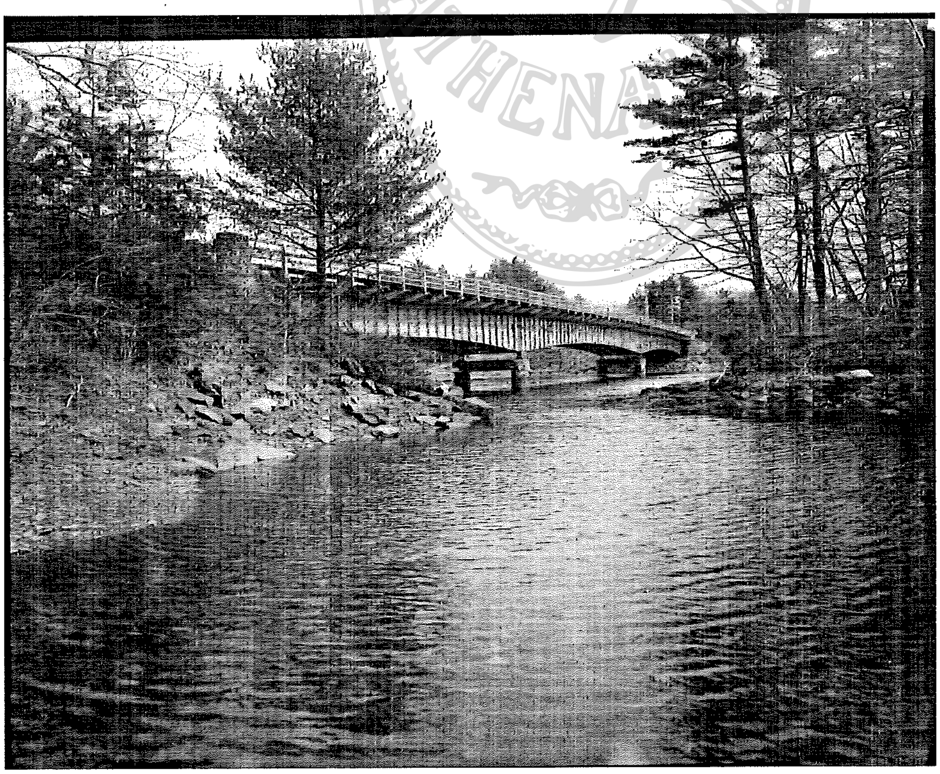


Photo 3.

REFERENCE PHOTOGRAPHS
Sagamore Avenue Bridge, Route 1A
NH STATE NO. 713 (Page 3)

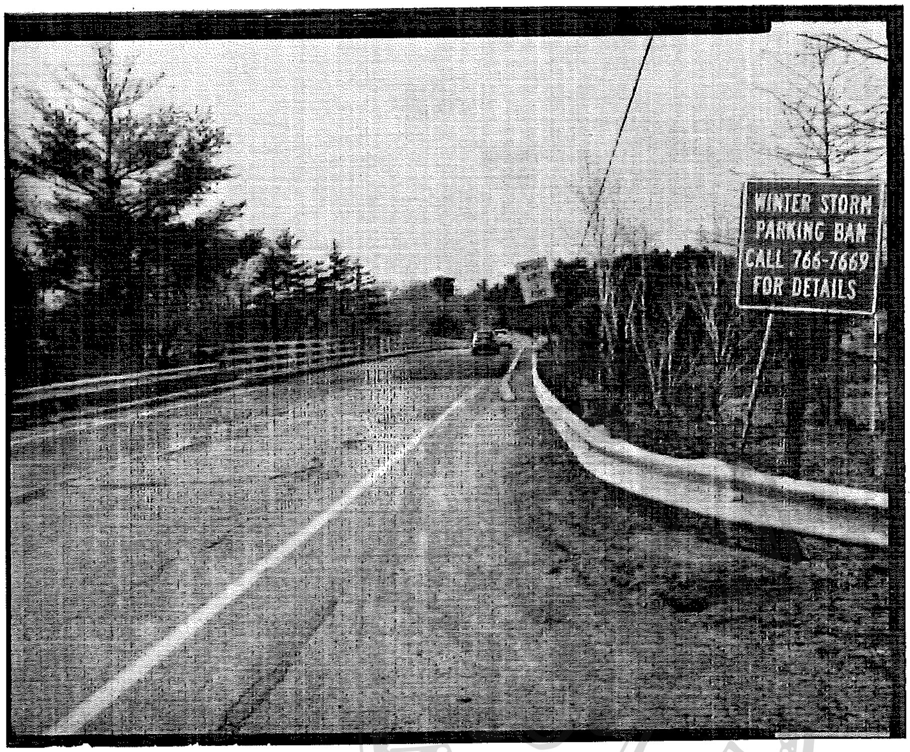


Photo 4.

Photo 5.

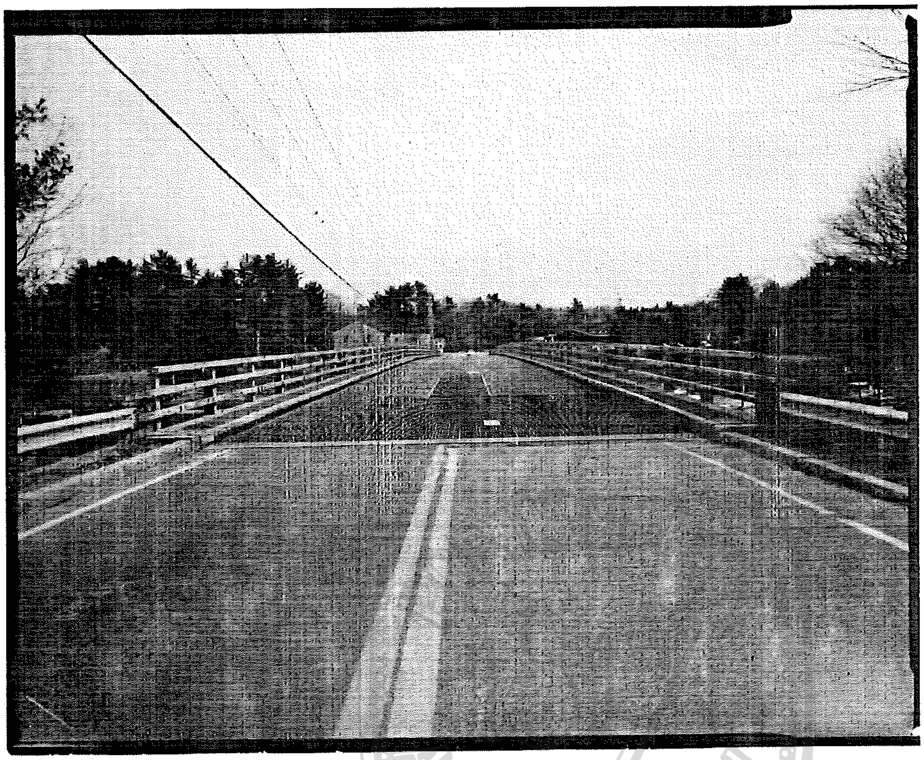


Photo 6.

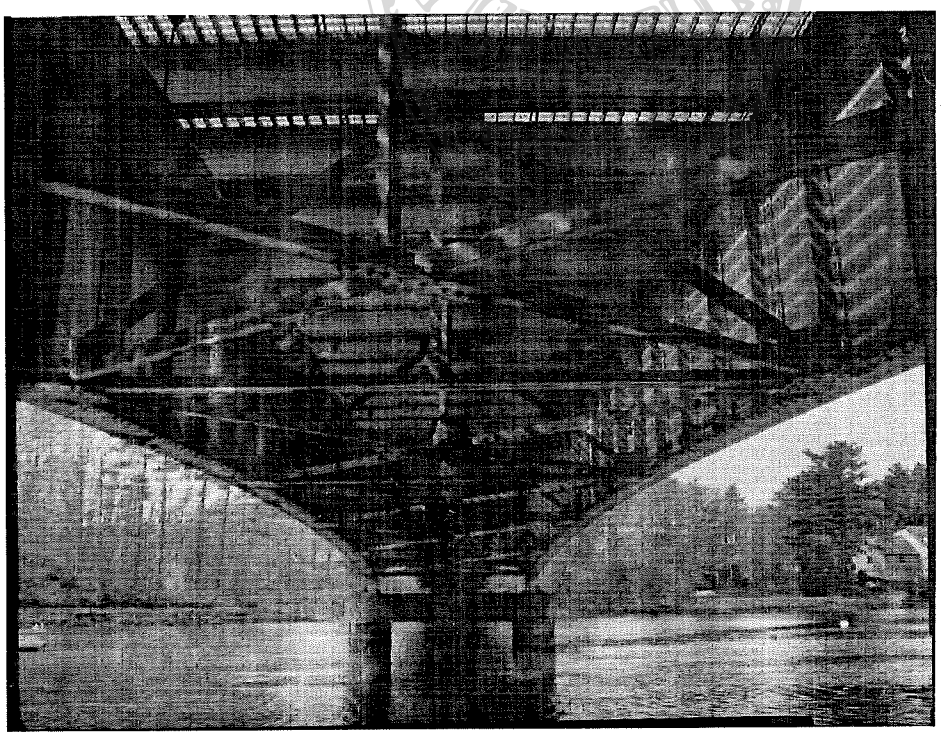


Photo 7.

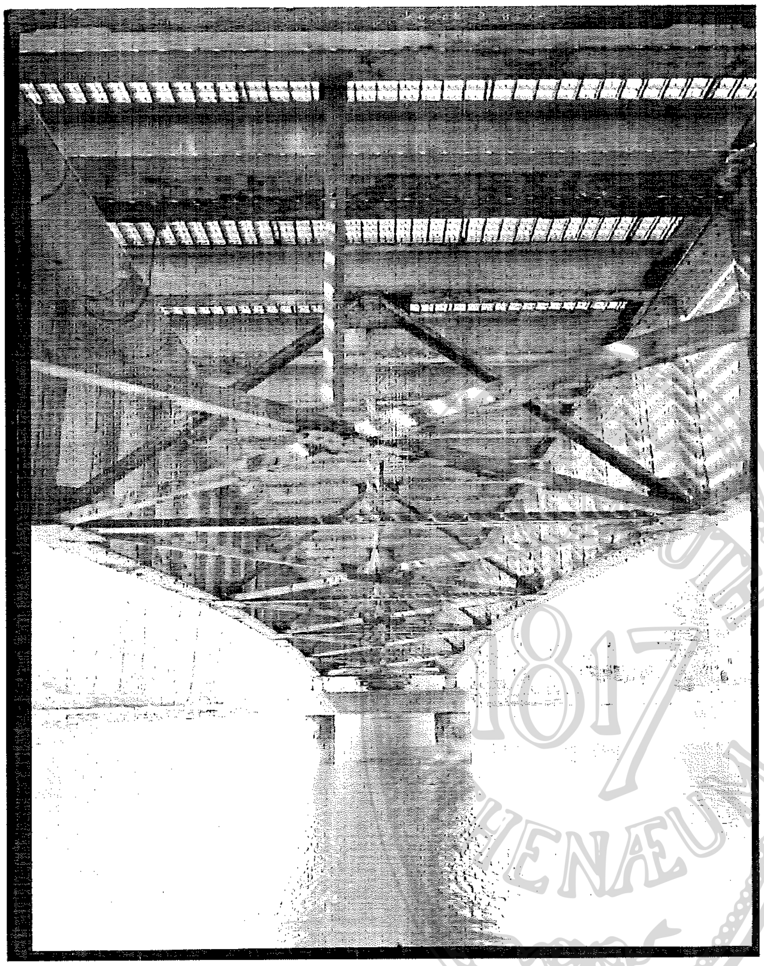


Photo 8.

Photo 9.

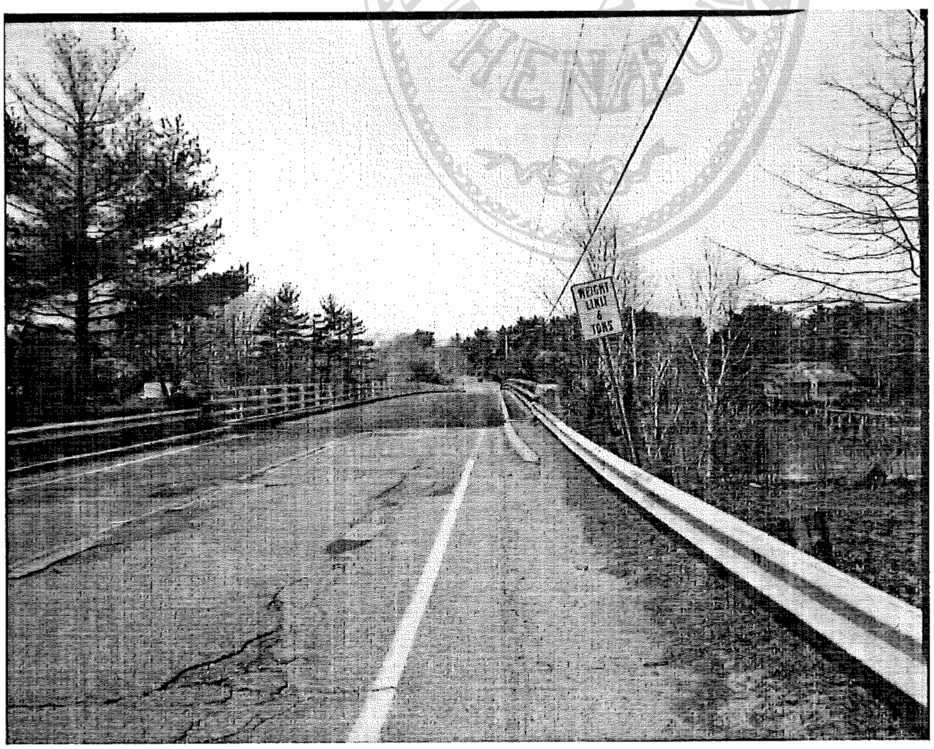


Photo 10.

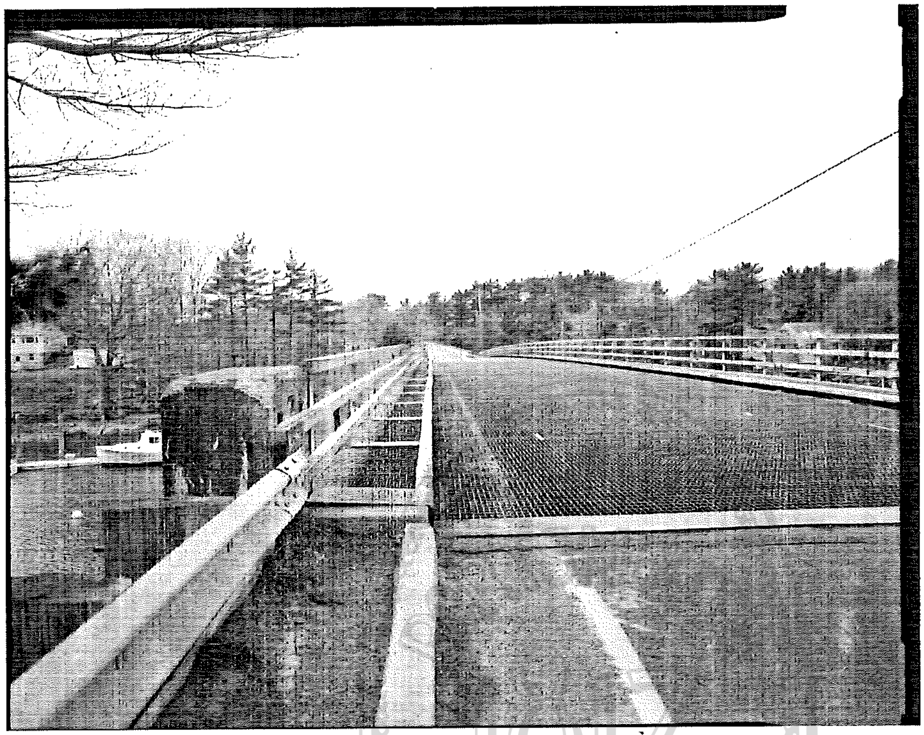


Photo 11.

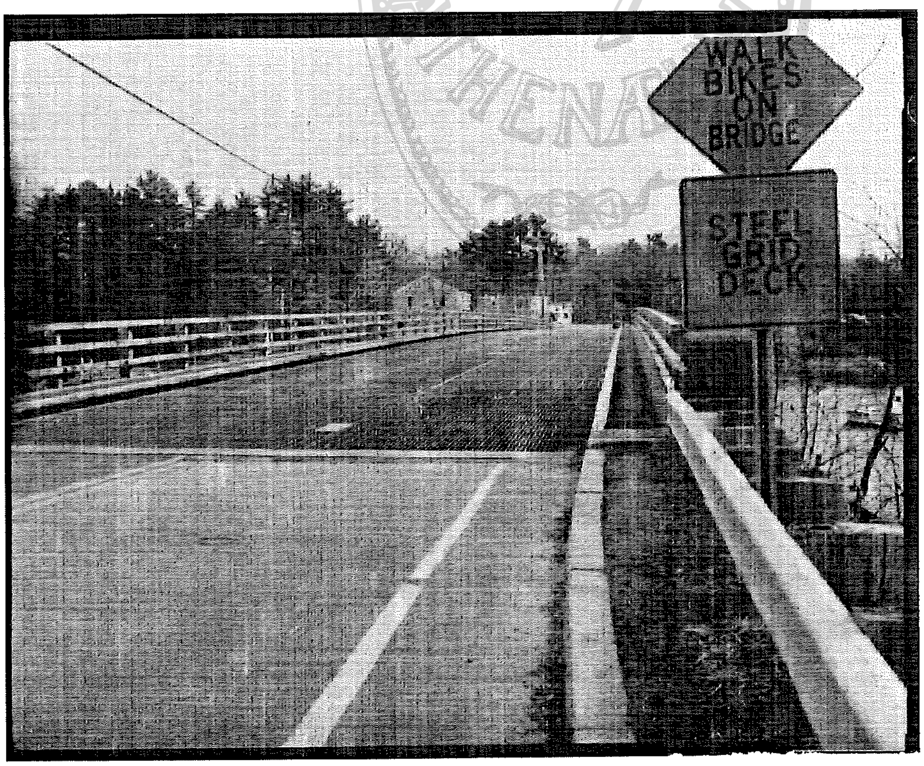


Photo 12.

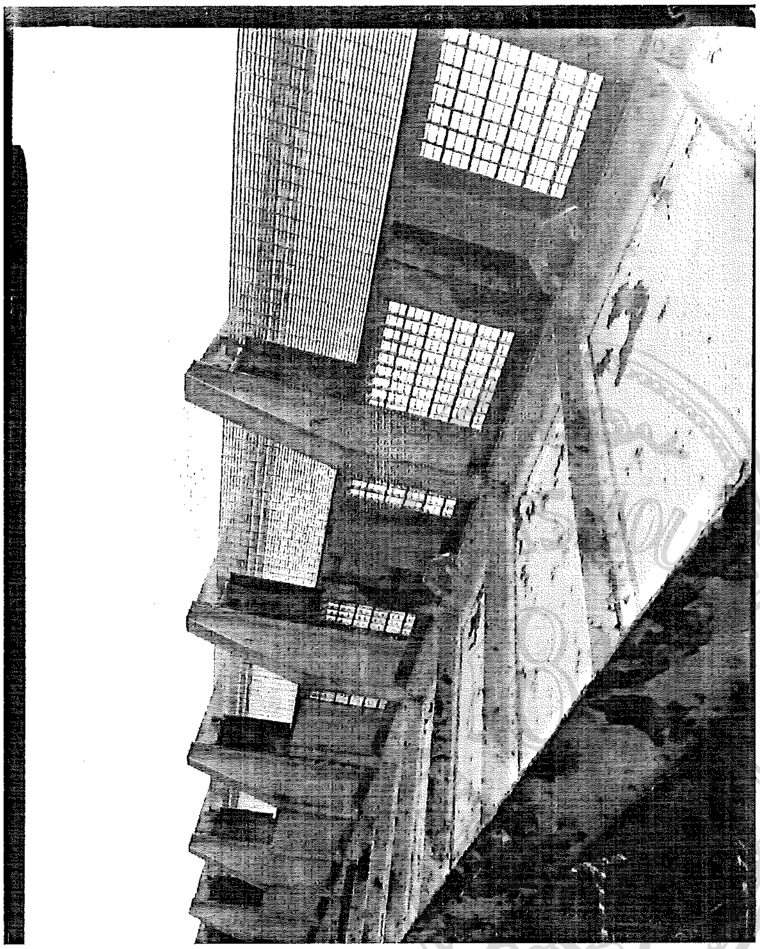


Photo 13.

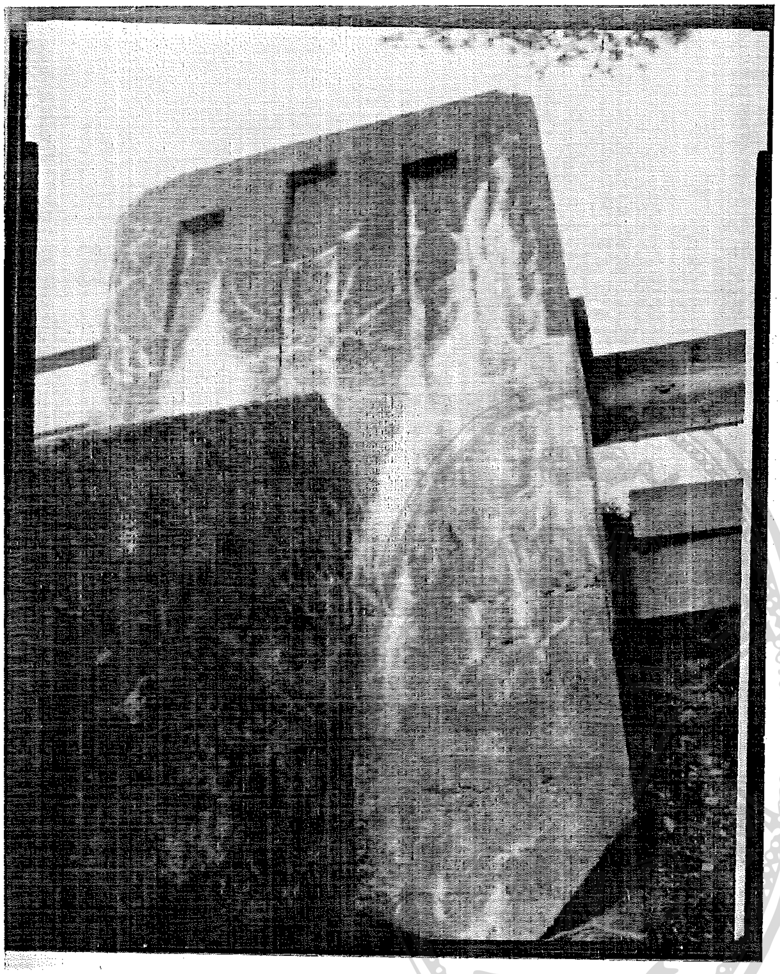


Photo 14.

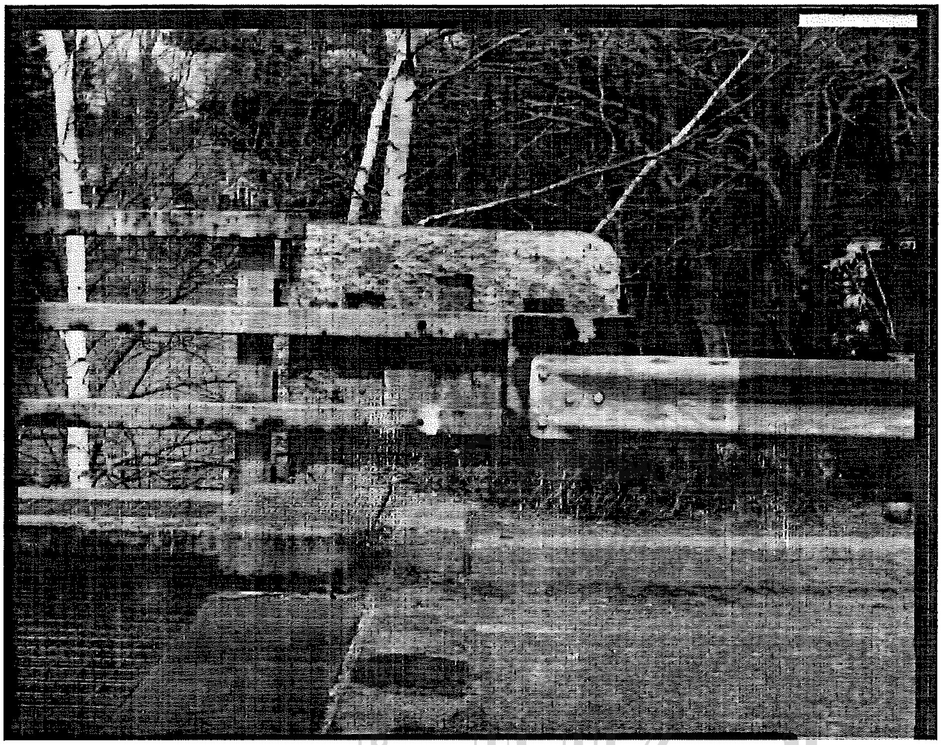


Photo 15.

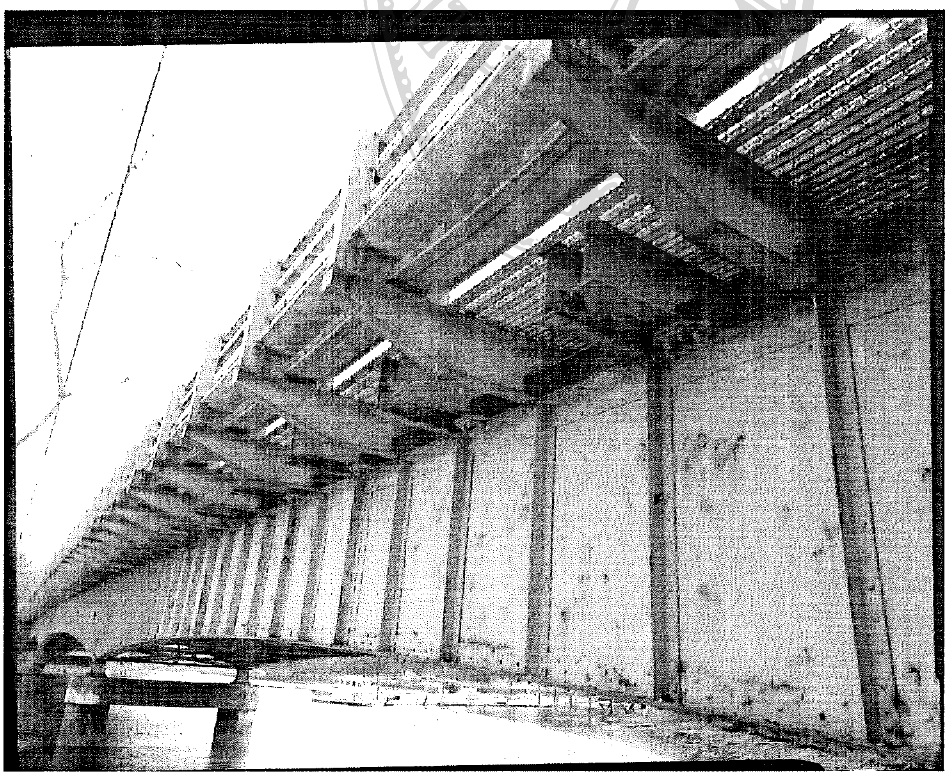


Photo 16.

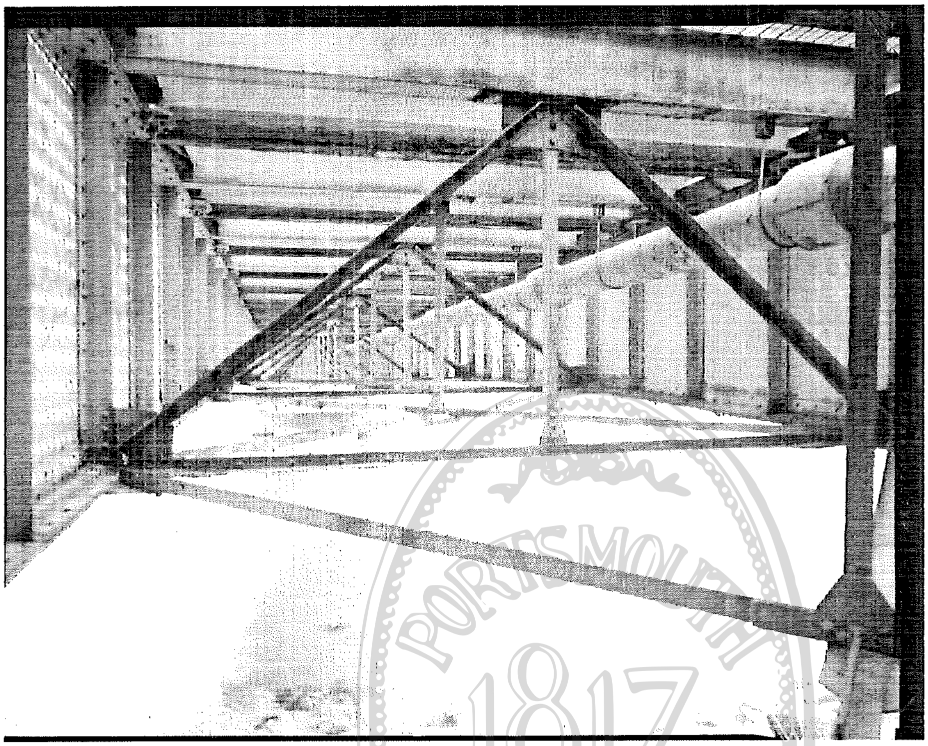


Photo 17.

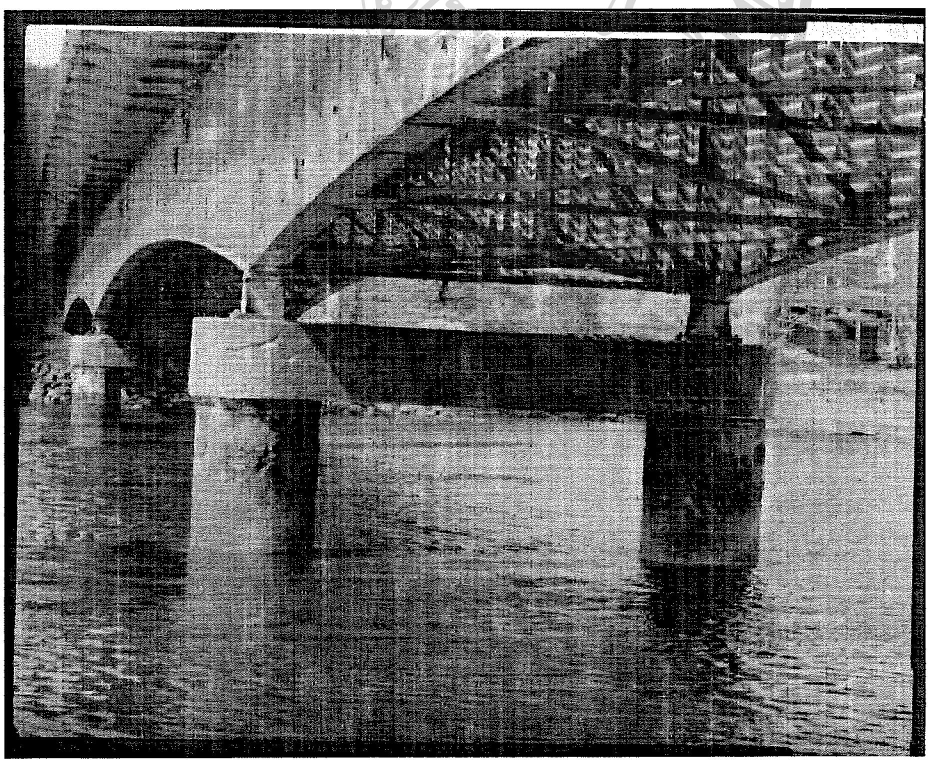


Photo 18.

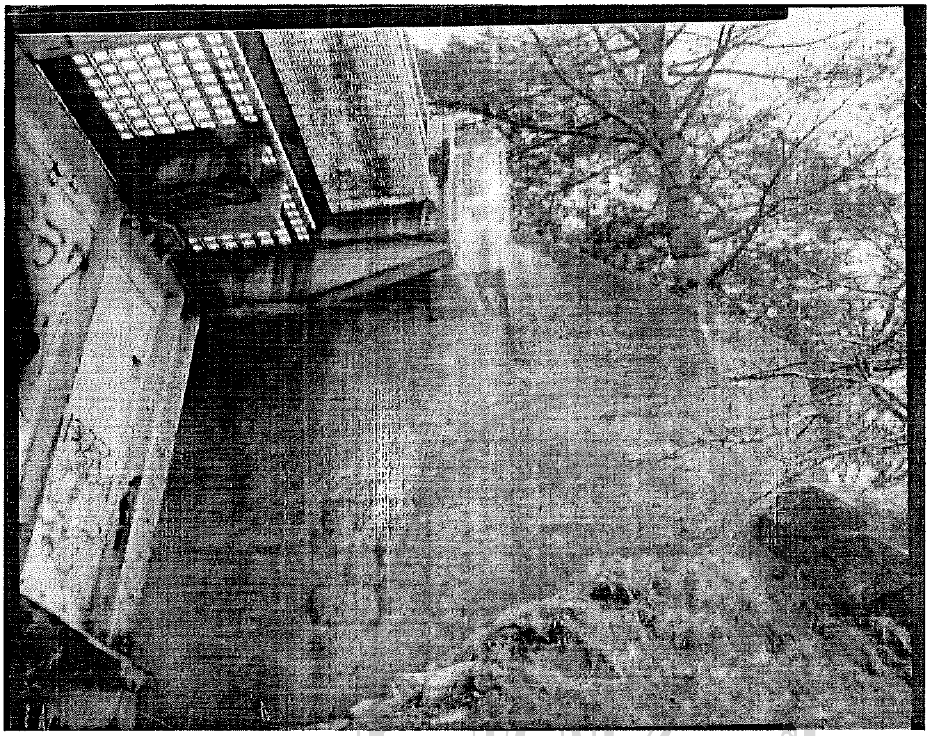


Photo 19.

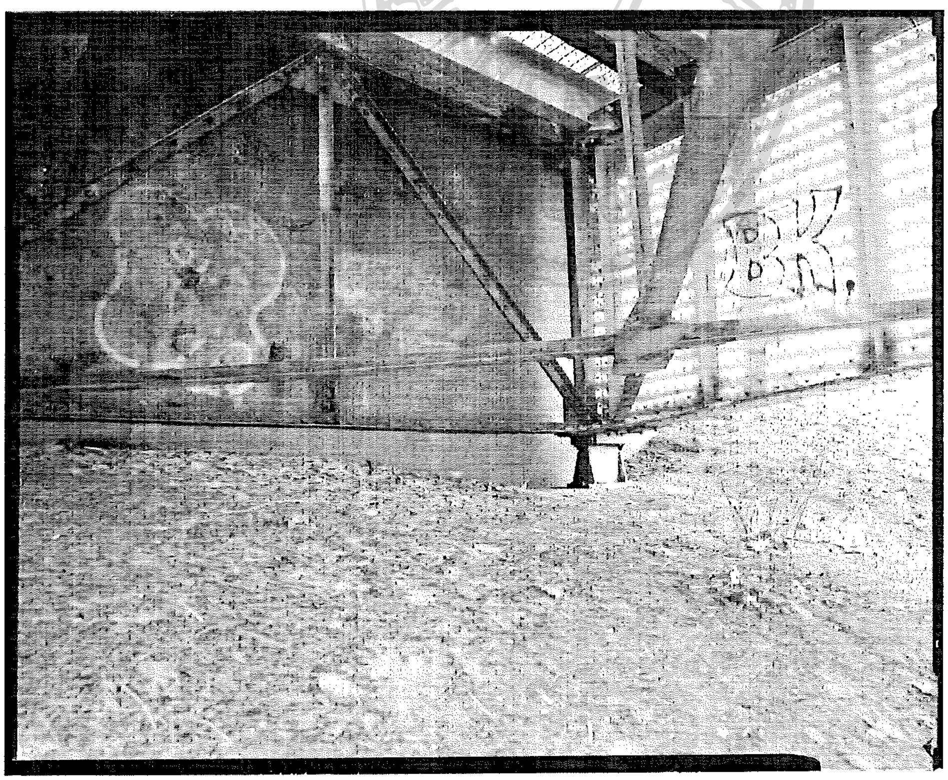


Photo 20.