MILL CREEK BRIDGE
(Deleware Bridge No. 9A)
State Route 6 over Mill Creek
Smyrna vicinity
Kent County
Delaware

HAER No. DE-39

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIEVE DATA

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

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LOCATION: State Route 6 over Mill Creek, Smyrna vicinity, Kent County, Delaware. USGS Smyrna, DE Quadrangle Universal Transverse Mercator Coordinates: 18.450360.4351100

DATE OF CONSTRUCTION: 1936

ENGINEER: J.F. Seiler and W.D. Keeney, Engineers, Service Bureau, American Wood Preservers' Association.

BUILDER: Delaware State Highway Department, Warren W. Mack, Chief Engineer, A.G. Livingston, Bridge Engineer

PRESENT OWNER: Delaware Department of Transportation

SIGNIFICANCE: The Mill Creek Bridge, one of three of its kind currently extant in Delaware, is an early representative example of a composite slab deck bridge, combining concrete and laminated timber.

PROJECT INFORMATION: The Mill Creek Bridge was recorded in June 1994 by the Cultural Resource Group of Louis Berger & Associates, Inc., East Orange, New Jersey, for the Delaware Department of Transportation (DELDOT). The recordation was undertaken pursuant to provisions of a Memorandum of Agreement between the Federal Highway Administration and the Delaware State Historic Preservation Office. Project personnel included Richard M. Casella, Architectural Historian, and Rob Tucher, Photographer.

DESCRIPTION

The Mill Creek Bridge (Delaware Bridge No. 9A) is located on State Route 6 over Mill Creek, approximately 1.7 miles east of Smyrna, Kent County, Delaware. The bridge is a two-lane, five-span composite concrete-timber deck span, measuring 100' in length overall. The area around the bridge is low, flat farmland and intertidal marshlands. Mill Creek is a tidal stream, approximately 100' wide and about 10' in maximum depth at the bridge (Figure 1).

The bridge is of a design proposed by the American Wood Preservers' Association in 1933, consisting of a laminated timber deck bonded to a concrete slab road surface with specially designed steel plate "shear developers." The five deck spans are identical, each measuring 20' long and 26' 4" wide. Each span is constructed of a concrete deck with an asphalt overlay bonded to the timber sub-deck which is visible from beneath the bridge.

The substructure consists of six wood pile bents spaced 20' apart on center. Each bent consists of five 12" pilings, 5' 6" on center, cross braced with two rows of 4" x 10" timbers meeting at the center pile, and capped with a 10" x 12" timber. In 1970 six new steel H-pile bents were added alongside the existing wood pile bents. Each steel bent consists of a 14" I-beam floor girder or "pile cap" supported at each end by 12" steel H-piles. Steel sheet pile bevel wing abutments were also constructed in 1970. The toe and flank of the abutment wings are protected against scour with concrete-filled sandbag retaining walls.

Each railing consists of five pre-cast sections attached to each span, each section measuring 19' 6" long overall. Each section consists of four posts measuring 9" x 12" x 24" high with chamfered tops, supporting two horizonal concrete rails measuring 6" square and 5' 3" long. The railing on the north side has been damaged by vehicular impact, and other areas of the curbing and railing are severely deteriorated with spalling and exposed reinforcing bar.

HISTORICAL INFORMATION

Background

The first settlement in the area near the Mill Creek Bridge was called Duck Creek, established about 1725 on Duck Creek about a mile north of present-day Smyrna. In 1768 lots were sold near the intersection of the King's Highway and "the Maryland road leading from Delaware Bay to the Chesapeake," and the resulting village became known as Duck Creek Crossroads (Hancock 1976:66). The "Maryland road" appears to be the current Route 6, which suggests that a crossing of Mill Creek, at or near the Mill Creek Bridge, dates to the mid-eighteenth century or earlier. In 1806 the General Assembly changed the name of Duck Creek Crossing to Smyrna. The area was primarily agricultural and known for its grain production, as was the

city of Smyrna in Turkey. In 1837 a steamboat dock known as Smyrna Landing was established on Duck Creek just east of town to provide service to Philadelphia.

At some time, a gristmill was established on the south edge of town along a small stream, ultimately called Mill Creek. The mill appears on the 1868 Beers map as "Sharpe's grist mill" located on Mill Street in Smyrna. Mill Creek flows east out of Smyrna about a mile, then curves north to empty into Duck Creek. At that time, Route 6 was called Woodland Beach Road and ran east out of Smyrna roughly parallel to Duck Creek (now the Smyrna River) to connect with the Delaware Bay at Bombay Hook Landing and Woodland Beach. In 1868 the road was bordered by large farms and undoubtedly used by farmers to move their produce into Smyrna or to Smyrna Landing for shipment by steamboat (Beers 1868).

The period following the Civil War was one of great growth for the Smyrna area as demand increased for its agricultural products, primarily grain and peaches. By 1880 Smyrna had five churches, two banks, two hotels, a library, and several manufacturing concerns turning out fertilizers, agricultural implements, fruit baskets, and wood products. Traffic along Woodland Beach Road in that year was brisk enough to justify the construction of a 42' iron pony truss over Mill Creek, replacing what was probably a wooden trestle bridge. This bridge remained in service until 1936, when it was replaced by the present Mill Creek Bridge. Over the next 20 years, more manufacturing interests located in Smyrna, including two foundries, three canneries, and two carriage works (Delaware Department of Transportation 1926; Hancock 1976:68).

In 1903 the Delaware legislature passed a State Aid Law which essentially marked the beginning of the state highway department; however, this act was repealed in 1905 and not reenacted until 1917. Meanwhile, in 1911, seeing the state falling behind its neighbors in developing permanent roads, General T. Coleman duPont offered to build a highway system, providing the General Assembly would grant the necessary legislation. Construction of 20 miles of the Coleman duPont Highway, a design considered years later to be far ahead of its time, began that year and was completed in 1917. The importance of good highways became immediately apparent to the populace, and the Highway Act of 1917 was passed by the legislature, officially creating the Delaware State Highway Department (Mack 1947:539, 544).

In 1935 major flooding washed out numerous roads and bridges, and at the urging of Governor C. Douglass Buck, the General Assembly directed the Highway Department to take over all highways previously maintained by the counties. Buck had served as Chief Engineer of the State Highway Department from 1921 until becoming Governor in 1929, and naturally saw a great importance in a good highway system. In addition to emergency repairs, a statewide upgrading of the county roads, funded by a four-cent gasoline tax, was begun that year and included widening, repaving, and the construction of new bridges. Innovative methods and materials for road and bridge building were encouraged, especially when they were economical or promised a long service life. The Mill Creek Bridge was built by the State Highway Department the

following year using a new composite concrete-timber deck design developed only three years earlier by the American Wood Preservers' Association. Two more bridges of the same design closely followed: the Omar Bridge (Delaware Bridge No. 445), built in 1938, and the Lake Bridge (Delaware Bridge No. 707), built in 1939. By 1938 the Highway Department had built over 200 new timber bridges since taking over the county highways (Delaware State Highway Department 1938:25; Mack 1947:549-550; Spero 1991:34, 37, 39).

History of the Mill Creek Bridge

According to the original bridge plans on record with the Delaware Department of Transportation, the Mill Creek Bridge was designed by A.G. Livingston, Bridge Engineer, and Warren W. Mack, Chief Engineer, of the State Highway Department. Mack joined the Highway Department at its inception in 1917 and served as chief engineer from 1929 to 1946. A hand-scribbled note on the plans reads "J F Seiler, Service Bureau, American Wood Preservers Bureau, 701 Chandler Bldg, Washington, DC." Seiler had published plans for a composite concrete-timber bridge in 1933 in the journal *Wood Preserving News* (discussed in detail below), and this evidently came to the attention of either Livingston or Mack and provided the basis for the Mill Creek Bridge design (Delaware Department of Transportation 1936; Mack 1947:535).

Construction of the bridge began on October 19, 1936, with the driving of 12" wood friction piles through as much as 25' of soft mud and into the compact sand layer below. At the same time, excavation for the abutments and the driving of the sheet pile backwalls were underway. The timber work for the deck commenced two weeks later and also took about two weeks to complete. Installation on the triangular steel plate "shear developers" and the 60-d uplift spikes required another five days. A total of 6,235 shear developers were installed, each requiring three slots to be cut in the deck timbers with a specially designed chisel. The concrete deck was poured beginning on November 24, and the bridge was completed on December 12 with the installation of the concrete railings (Delaware Department of Transportation 1936; Seiler and Keeney 1933:160-163).

The bridge was featured in the Annual Report of the State Highway Department for 1936 with two photos of the bridge and a short note which read:

> The Mill Creek Bridge consists of a concrete floor and railings supported by a creosoted timber pile foundation and a laminated creosoted timber floor. It is of new and very economical design and its serviceability will be watched with interest by the departments engineers [Delaware State Highway Department 1936:25].

The Mill Creek Bridge apparently provided uninterrupted service until 1970, when a rehabilitation of the substructure was undertaken. The work included replacement of the original timber backwalls with concrete and steel sheet piling abutments, and the driving of steel H-piling bents alongside the deteriorated wooden pilings (Delaware Department of Transportation 1970).

Composite Timber-Concrete Deck Bridges

Interest in concrete-timber structures began in the northwest United States in the early 1920s as an effort to combine the long-wearing quality of a concrete deck with the low-cost of a timber substructure. The abundance of cheap, high-quality timber in the northwest seems to have been a major factor. In 1924 experiments on concrete-timber beams were undertaken by the City of Seattle Engineers Office and the University of Washington to measure the bond between the concrete and wood and to test various types of shear connections. George D. Burr, an assistant engineer with the city, designed and performed the experiments, the results of which were published in 1926 by the University of Washington Experimental Station. Burr's experiments tested a deck consisting of wood stringers measuring 4" x 14" and a cast-in-place concrete slab. Steel spikes, measuring 3/8" x 8" were driven into the top of the stringers to a depth of 5" to act as shear and uplift connectors. Stringer spacing was determined by the loading requirements, and temporary form boards were placed between the stringers during the pouring of the deck. Burr and A.W. Munster appear from the literature to have built the first bridge that can be considered a true composite timber-concrete structure, as well as the first composite structure using a laminated timber sub-deck. Working for the city, the two engineers designed a composite deck for the east approach of the Spokane Street Bridge in Seattle, completed in late 1924. The structure was designed as a temporary bridge during construction and was evidently a means of testing the design before putting it into widespread use (Burr 1933:523).

Articles on composite concrete-timber structures do not appear in the engineering journals again until 1932. In that year, the Oregon State Highway Commission began studying the use of timber bridges with the idea of developing an economical highway bridge that would have widespread appeal and increase the demand for timber, Oregon's largest industry. Studies were carried out by C.B. McCullough, Bridge Engineer, under the direction of R.H. Baldock, Oregon State Highway Engineer. The Oregon system is similar to Burr and Munster's composite T-beam design, with the addition of "daps," or notches cut out of the top of the stringers to key the concrete and resist shear. A bridge following the McCullough design was built in Oregon in 1932 (McCullough 1932:213, 214).

The design on which the Mill Creek Bridge is based was proposed by J.F. Seiler in 1933 in the November issue of *Wood Preserving News*. Seiler was an Engineer with the Service Bureau of the American Wood Preservers' Association and utilized the engineering laboratory of George Washington University at Washington, D.C., to conduct his experiments. Seiler's objective was

to combine the tensile strength of wood with the compression strength of concrete into a low-cost, long-life structure. The ideal design would fall in cost between that of an all-timber structure and that of a steel-reinforced concrete structure, and would be easily built with a minimum of skilled labor and special equipment (Timber Engineering Company 1956:219).

Seiler's design differed from previous designs in several ways: it used laminated timbers as in the Burr design of 1926, but of alternating width to create longitudinal channels that would act as keys and increase the surface area for bonding with the concrete. Each timber was laminated to the next with nails, creating a continuous solid deck of any desired width. The solid deck did not require additional formwork and was of sufficient strength on its own to carry the workers and equipment during the concrete pouring operation. The most clever aspect of the design was the utilization of specially designed and fabricated "shear developers," or "shear keys" which allowed the shear stresses to be transmitted to the endgrain of the timbers. The method of attaching the shear plates with three slots in the timbers allowed the plates to act as beams rather than as a cantilever, as in other types of shear keys (Seiler 1933:144-145).

The first bridge to be built according to the Seiler design was the Tampa-Clearwater Causeway across Old Tampa Bay, Florida, completed in 1934. The 3,500' trestle structure consisted of 167 Seiler composite deck spans, each 20' in length, and a 110' bascule lift span. Over the next decade, composite timber-concrete construction came into general use for highway bridges, hangar aprons, wharves, piers, buildings, and platforms, and by 1943 the structures were found in 12 states and Canada. The Oregon State Highway Department alone had built over 180 composite bridges, with a total length of 20,000'. During the war years, reinforcing steel became scarce, sparking renewed interest in wood-reinforced concrete. Research and testing of composite timber-concrete beams and slabs were undertaken in the engineering departments of several universities. The most prominent work was conducted from 1938 to 1942 by F.E. Richart, Research Professor of Engineering at the University of Illinois, and his Graduate Research Assistant, C.B. Williams (Boyd 1943:96; McCullough 1943:429; Richart and Williams 1943:253; Seiler 1934:132; *Wood Preserving News* 1934:20).

Richart and Williams tested the Seiler composite slab system, which had become the most popular system due its economy of materials and ease of construction. Fifteen types of beams were tested which utilized a variety of shear connection methods, including triangular steel plates, spikes, lag screws, and sloped daps cut into the wood. The triangular plates of the type developed by Seiler, in combination with 60-d spikes, yielded the highest test results. The tests conducted on the Seiler system by Richart and Williams led to the wide adoption of the design, which is now cited in most modern engineering manuals on the subject (American Institute of Timber Construction 1966:120; Richart and Williams 1943:255,261; Timber Engineering Company 1956:220).

In 1984 the Delaware Department of Transportation built a timber-concrete composite deck bridge in Sussex County (Delaware Bridge No. 235) identical in design to the Mill Creek Bridge. The purpose of Bridge No. 235 was to replace an existing timber bridge with a low-cost, low-volume bridge with a concrete wearing surface. The Seiler design was determined to be the most cost effective choice at the time. In the years since, glue-laminated timber deck bridges with a hot-mix wearing surface have replaced the nail-laminated deck as the structure of choice for overall economy and service (Mike Angelo, personal communication 1994).

REFERENCES CITED

American Institute of Timber Construction
1966 *Timber Construction Manual.* John Wiley and Sons, Inc., New York.

Angelo, Mike
1994 Personal communication, July 7, 1994. Chief Road Design Engineer, Delaware Department of Transportation, Dover, Delaware.

Baldock, R.H., and C.B. McCullough
1933 *Loading Tests on a New Composite Type Short Span Highway Bridge Combining Concrete and Timber in Flexure.* Oregon State Highway Commission, Technical Bulletin No. 1. Oregon State Highway Commission, Seattle.

Boyd, Alfred
1943 Concrete Reinforced with Timber. *Engineering News-Record*, March 25, 1943, p. 96.

Beers, D.G.
1868 *Atlas of the State of Delaware.* Pomeroy and Beers, Philadelphia.

Burr, George D.
1933 Combining Concrete and Timber for Trestle Decks. *Engineering-News Record*, April 27, 1933, pp. 523-524.

Delaware State Highway Department
1936 *Annual Report of the State Highway Department of the State of Delaware.* Delaware State Highway Department, Dover, Delaware. Located in Division of Historical and Cultural Affairs, Department of State, Hall of Records, Dover, Delaware.

1938 *Annual Report of the State Highway Department of the State of Delaware.* Delaware State Highway Department, Dover, Delaware. Located in Division of Historical and Cultural Affairs, Department of State, Hall of Records, Dover, Delaware.

Delaware Department of Transportation

n.d. Bridge No. 9A File. Located at the Delaware Department of Transportation, Dover, Delaware.

1926 Microfilm plans for Contract No. CK34, April 6, 1926. Located at the Delaware Department of Transportation, Dover, Delaware.

1936 Microfilm plans for Contract No. 412, March 31, 1936. Located at the Delaware Department of Transportation, Dover, Delaware.

1970 Microfilm plans for Contract No. 70-05-001, June 22, 1970. Located at the Delaware Department of Transportation, Dover, Delaware.

Engineering News-Record

1925 Concrete Pavement on Timber Floor of Bridge Approach Trestle. *Engineering News-Record*, vol. 95, no. 17, October 22, 1925, p. 683.

1926 Missouri Builds Timber Trestles with Concrete Floor. *Engineering News-Record*, vol. 96, no. 18, April 1, 1926, p. 536.

Hancock, Harold B.

1976 *History of Kent County, Delaware.* Dover Litho Publishing Company, Dover, Delaware.

Mack, Warren W.

1947 A History of Motor Highways in Delaware. In *Delaware, A History of the First State*, edited by H. Clay Reed, pp. 535-550. Lewis Historical Publishing Co. Inc., New York.

McCullough, Conde B.

1932 Timber Highway Bridges in Oregon. *Engineering News-Record*, vol. 109, no. 8, August 25, 1932, pp. 213-214.

1943 Oregon Tests on Composite (Timber-Concrete) Beams. *Journal of the American Concrete Institute* 14(5):429-440.

Richart, F.E., and C.B. Williams
1943 Tests of Composite Timber-Concrete Beams. *Journal of the American Concrete Institute* 14(4):253-276.

Seiler, J.F.
1933 New Type of Composite Beam. *Wood Preserving News*, vol. 11, no. 11, November 1933, pp. 144-158.

1934 Composite Bridge Deck Under Traffic on Tampa-Clearwater Project. *Wood Preserving News*, vol. 12, no. 10, October 1934, pp. 132-143.

Seiler, J.F., and W.D. Keeney
1933 Design of Composite Slab Highway Bridge Deck. *Wood Preserving News*, vol. 11, no. 12, December 1933, pp. 159-171.

Spero, P.A.C. and Company
1991 *Delaware Historic Bridges: Survey and Evaluation*. Delaware Department of Transportation, Division Of Highways, Dover, Delaware.

Timber Engineering Company
1956 *Timber Design and Construction Handbook*. F.W. Dodge Corporation, New York.

United States Geological Survey [USGS]
1993 *Smyrna, Delaware*. 7.5-Minute Topographic Quadrangle. United States Geological Survey.

Wood Preserving News
1934 Composite Timber-Concrete Deck Used on Tampa Clearwater Bridges. *Wood Preserving News*, February 1934, pp. 20-23.

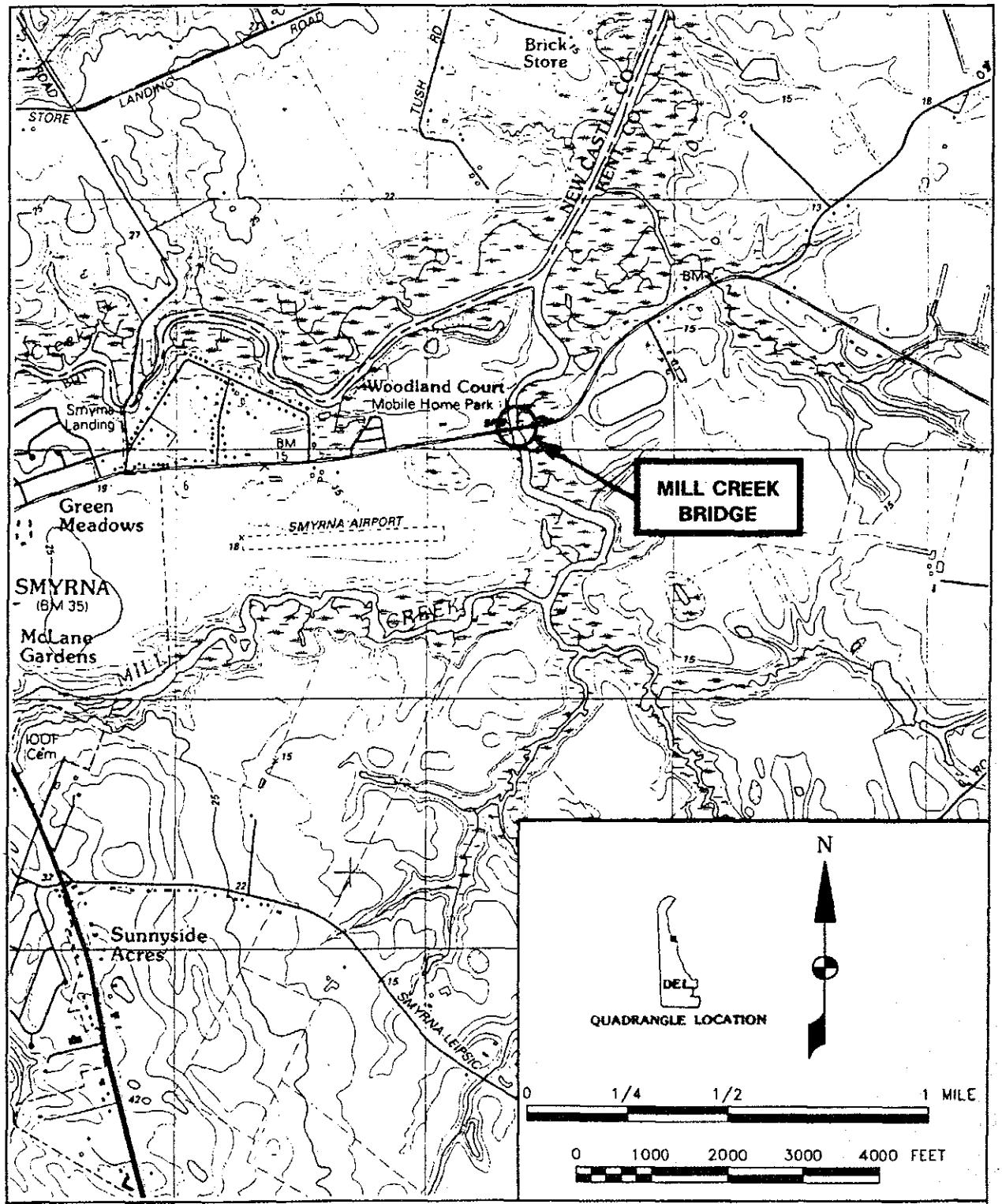

FIGURE 1: Location Map

SOURCE: USGS 7.5 Minute Quadrangle, Smyrna, DEL, 1993