THOMAS A. EDISON BRIDGE
U.S. ROUTE 9 OVER THE RARITAN RIVER
SOUTH AMBOY VICINITY
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NEW JERSEY

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

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

HISTORIC AMERICAN ENGINEERING RECORD

THOMAS A. EDISON BRIDGE

HAER No. NJ-119

LOCATION:	U.S. Route 9 over the Raritan River, South Amboy vicinity, Middlesex County, New Jersey USGS Perth Amboy, NJ-NY and South Amboy, NJ-NY Quadrangles; UTM Coordinates: 18.559280.4484300
ENGINEERS:	Morris Goodkind, Chief Bridge Engineer, and W.F. Hunter, Bridge Engineer, New Jersey State Highway Department
CONTRACTORS:	Peter F. Connolly Co., Folhaber Pile Co., J.F. Chapman Co., Eisenberg Construction Co., Bethlehem Steel Co., and John G. English and Joseph Nesto Co.
BUILDER:	New Jersey State Highway Department
DATE OF CONSTRUCTION:	1938-1940
PRESENT OWNER:	New Jersey Department of Transportation
PRESENT USE:	Highway bridge
SIGNIFICANCE:	The Thomas A. Edison Bridge is an important example of a very large and early continuous deck plate girder highway bridge. It was the largest, highest, and longest span bridge of its type in the United States when completed. Its erection by the Bethlehem Steel Company involved the lifting of the world's longest (260') and heaviest (198 tons) girder to a height of 135'. Morris Goodkind made important contributions to twentieth-century highway bridge engineering.
PROJECT INFORMATION:	The Edison Bridge was recorded in January 1998 by the Cultural Resource Group of Louis Berger & Associates, Inc. (Berger), East Orange, New Jersey. This documentation, prepared for the New Jersey Department of Transportation, was undertaken in accordance with a Memorandum of Agreement among the New Jersey State Historic Preservation Officer, the Federal Highway Administration, and the Advisory Council on Historic Preservation signed in July 1995.

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DESCRIPTION

The Edison Bridge is a 29-span continuous plate girder deck bridge that is 4,391' in length and carries four lanes of U.S. Route 9 in a northeast-southwest direction over the Raritan River. The bridge connects South Amboy on the south side of the river with Perth Amboy on the north side, and is located roughly 3,000' upstream of the Victory Bridge. The bridge is supported by open, reinforced concrete piers, reaching a maximum height of 135' over the channel, and by concrete U-type abutments. The approaches are all simply supported. At the north end the approach consists of six 152'-6" spans and six 84'-6" spans. At the south end the approach consists of eight 132'-6" spans. Three three-span continuous girders form the nine main spans over the river. The center girder consists of two 200' spans and a middle span over the channel of 250', for an overall length of 650'. The other two continuous girders are 600', overall with three 200' spans each. The bridge is 58' wide overall, with two 24' travel lanes, a median barrier about 4' wide, and sidewalks 3' wide overall. The setting is a mostly commercial environment of mixed land use; the south approach crosses marshlands.

The piers are variously one- or two-story concrete frames with two rectangular columns or shafts which rest on solid, granite-faced pedestals. The pedestals rise 20' above mean low water (MLW) and measure approximately 17' by 60'. The rock-faced granite facing is pointed with lead for added resistance to saltwater deterioration. The sizes of the pier shafts vary depending on their location and the length of span they support. The first-story shaft of the largest main-span pier measures 13' by 10'-4". The second-story section of the shafts (above the cross-tie) are stepped in or "relieved" 1' in each dimension. The corners of the pier shafts are stepped in with 2' wide by 8" deep notches along their entire length to enhance the appearance of slenderness. The cross-ties (on two-story frames) and pier caps are square and also slightly graduated down in dimension from the shafts. The U-type reinforced concrete abutments are typical, fitted with concrete open-balustrade railings, and absent of any significant architectural detailing other than linear reliefs.

The main span girders are 13' deep through the middle sections and 15' deep over the piers, except for the ends of the 250' span which are 21' deep over the piers. The 250' channel span girder (which is actually 260' in length because the splice point extends beyond the pier) was at the time, the longest, deepest, and, at 200 tons, the heaviest girder ever fabricated and erected in the U.S. The top flanges of all the main girders consist of four 8" by 8" by ⅞" angles with 26"-wide by ½"- and ⅝"-thick cover plates built up to a thickness of over 3" over the piers.

The floor system consists of built-up (plate girder) floor beams, 5'-6" deep, set flush with the top flanges of the main girders and additionally supported with built-up knee braces connected to the girder's bottom flange. The floor beams are spaced 25' apart. A lateral cross-bracing system of 12" I-beams interconnects the girders and the bottom flanges of the floor beams. Deck stringers are 21" I-beams, spaced 6'-6" apart. The stringers are inset between the floor beams, supported by angles, with the top flange extending about 4" above the floor beams for imbedding within the deck.

The deck is a 9"-thick concrete slab, reinforced with welded truss-type reinforcement. The deck slab on the continuous spans is also made continuous over the piers by reinforcement, and with connector plates joining the floor joists over the top of the floor beams. The concrete deck is topped with an asphalt riding surface.

The welded steel bridge railing is a plain rectilinear balustrade constructed from standard rolled shapes and plate. The posts are square, consisting of two 15" channels turned inward, and spaced between 21' and 25' apart depending on the length of the span to which they are attached. The hand rail is simply two 2½" angles and a cover plate with the corners rounded. The vertical balusters are 4½" T-shaped members, spaced 7½" apart and attached directly to the sidewalk deck with angles.

Architecturally, the bridge design can best be described as modern, with form following function. By the late 1930s, the era of adding extraneous decorative details to bridges, particularly forms molded into the concrete, was largely over. Clean lines, "graceful" curves, linear shadow lines, and the repetition of simple shapes, such as the vertical stiffeners of a plate girder, were now viewed as aesthetically pleasing representatives of the "pure form" of engineering science.

Two short, single-span, encased-girder deck spans, today known as the north and south Route 9 Victory Circle Overpass bridges, were built in conjunction with the Edison Bridge. The structures were built to carry the approach highway over a traffic circle approximately 3,000' south of the bridge. The south bridge (No. 1209153) and the north bridge (No. 1209154), are structurally identical, being 63' wide overall and spanning 55'. The reinforced concrete deck is supported by a total of ten 33"-wide flange I-beams encased in concrete and cast integral with the deck. The concrete railings are the typical open vertical balustrade type. The abutments are decorated with rectilinear detailing including raised vertical paneling at the corners and horizontal recessed flat and V-groove scoring and banding on the sides and faces.

HISTORICAL BACKGROUND

The first established commercial crossing of the Raritan River in the vicinity of the Edison Bridge was Radford's Ferry. The ferry opened in 1684 or shortly thereafter to connect Perth Amboy and South Amboy. In that year, New Jersey Deputy Governor Lawrie had established a stage ferry between New York and Perth Amboy, and Radford's Ferry provided a connection for those travelers continuing south along the shore. Prior to the ferry it was necessary for those on horse or with wagons to follow the Raritan up to New Brunswick, where at low tide the river could generally be forded. The shoreline transportation route naturally grew in importance and use with the growth of the communities it served and as a direct route between New York and Philadelphia. To meet the traffic demand, two or more ferries operated simultaneously between Perth Amboy and South Amboy through most of the nineteenth century (*Perth Amboy Evening News* 1940a:17; 1959:2).

The building of the Camden and Amboy Railroad between Bordentown and South Amboy in 1833 was an immediate success. The line carried 110,000 passengers in its first year of operation. The Amboys were located on the principal transportation route between New York and Philadelphia up until the construction of the New Jersey Railroad between Jersey City, Newark, and New Brunswick in 1838. The New Jersey Railroad built a combined railroad and highway bridge over the Raritan River at New Brunswick in 1839. The following year the Camden and Amboy Railroad began construction of its second line between Trenton and New Brunswick, to connect and share traffic with the New Jersey Railroad. With a connection to the Philadelphia and Trenton Railroad completed in 1840, the Camden and Amboy established the first all-rail service between Jersey City and Philadelphia. The shift of the primary thoroughfare to New Brunswick slowed the growth of the Amboys and dramatically reduced traffic, but it did not doom the economy of Perth Amboy (A.G. Lichtenstein n.d.:n.p.).

Perth Amboy possessed an excellent sheltered deepwater port. In 1871 the Lehigh Valley Railroad began construction of a new line called the Easton and Amboy Railroad that would connect its Pennsylvania coal fields with the port of New York. The Lehigh Valley built a huge coal terminal at the line's terminus in Perth Amboy, which rapidly transformed the community into a busy industrial city. In 1875, with the construction of the New York and Long Branch Railroad bridge across the mouth of the Raritan River, Perth Amboy and South Amboy were joined by a bridge for the first time. The line ran from Long Branch to Perth Amboy, where it made connections with branches of the Pennsylvania and the Central New Jersey railroads. This new line was instrumental in further developing seaside resorts along the New Jersey shore in Monmouth and Ocean counties, and was soon transporting hordes of summer beachgoers (A.G. Lichtenstein n.d.:n.p.).

The railroad bridge stalled the construction of a highway bridge over the mouth of the Raritan River until 1910, when the "county" bridge was erected. Within a few years the county bridge was inadequate to handle the weight of increasingly larger trucks and the traffic volume caused by the burgeoning number of automobiles. Traffic problems were especially acute on summer weekends as people discovered the joy of motoring to the beaches. The increase in pleasure boating led to more frequent openings of the bridge, compounding the problem. Talk of a new bridge began as early as 1916, and by 1920 the State Highway Department had taken over the bridge from the county and was promising to build a new bridge. In 1924 the state commissioned a report entitled "Study of Traffic on State Route No. 4 Between Perth Amboy and Asbury Park," which presented a method for "handling this most unusual traffic situation" (New Jersey State Highway Commission 1924:1). The state project that immediately followed the report was completed between 1924 and 1926 and resulted in the construction of a entirely new bridge named Victory Bridge, and the improvement of the approach routes and connecting roads (*Perth Amboy Evening News* 1946:n.p.).

Once again, the anticipated traffic loads on the new bridge were grossly underestimated. When the Victory Bridge was planned, its height of 28' above the water was declared to be sufficient to permit "most shipping" to pass under it without opening the draw. This proved not to be the case, and within a few years "insufferable" weekend traffic snarls were again paralyzing the Amboys. In 1939, for example, the draw was opened 2,979 times (Goodkind 1940a:491; *Perth Amboy Evening News* 1940a:18)

The traffic situation was aggravated in Perth Amboy by the density of cross streets along Route 4 through the city. Along the five-mile stretch between Victory Bridge and the Woodbridge cloverleaf, there were 11 traffic signals and 69 cross streets. "Despite the best efforts of the Perth Amboy, South Amboy and Woodbridge police to keep traffic moving, jams occurred each summer weekend" (*Perth Amboy Evening News* 1940a:18). It was apparent to the locals that a second bridge, not a replacement, was required, and that it must be a fixed bridge, high enough for any conceivable vessel to freely pass. When designs for the new bridge were first revealed by the state, specifying a low-level bridge with a draw, the objections of local officials and citizens were so great that the highway department was forced to change its plans to an elevated fixed structure with 135' of clearance (*Perth Amboy Evening News* 1940a:21).

History of the Bridge

The proposed bridge was to be the centerpiece of a plan which included the construction of a new limited-access highway around downtown Perth Amboy. The highway department called the new road the "Route 35 Extension from the Woodbridge cloverleaf to Keyport," but it became generally known as the Perth Amboy By-pass (Goodkind 1940a:491; New Jersey State Highway Department 1939:n.p.).

The state legislature appropriated funding for the project in stages. In 1935 it authorized construction of the by-pass road, and approaches to the bridge were authorized. Work began that year in South Amboy with the re-routing of Routes 35 and 4 and the construction of a new intersection of those roads at a traffic circle north of South Amboy center. The approach to the Victory Bridge from the new circle was realigned and improved as well. Under the Edison Bridge contract, the new "Victory Circle" would be spanned by the two short deck bridges of the Route 35 Extension, forming the south approach to the new bridge. The work was performed by the Franklin Contracting Company and the Jannarone Contracting Company under a number of separate contracts which extended into 1937 (New Jersey State Highway Department 1935, 1937).

In 1937 the legislature approved $1,000,000 to cover the cost of the construction of the river piers for the new bridge. Finalization of the project's design and the preparation of contract documents to be put out for bids got underway in earnest within the bridge division of the highway department. In August 1938 full funding for the bridge's estimated $4,000,000 cost was approved by the legislature upon the receipt of a federal grant from the Public Works Administration (PWA) in the amount of 45 percent of the total cost. The lawmakers designated the name of the new bridge the Thomas A. Edison Bridge (Goodkind 1940a:491).

The Edison Bridge was made possible under the third PWA program to be funded by Congress. Approved in 1938, following a new surge in business recession and unemployment, the program provided about one billion dollars in grants to cover 45 percent of project costs. Congress assured intensive application of the funds by allowing only six months for project allocations and the start of construction, and eighteen months more for completion of the work. With several thousand projects already approved, including construction of the Edison Bridge, and a flood of new project applications from cities and states, the entire fund was dispensed before the end of the year. Funding was provided to over 7,000 projects, representing over two billion dollars in total construction (*Engineering News-Record* 1939b:60).

The design of the Edison Bridge was the direct responsibility of Morris Goodkind, chief engineer of the bridge division of the New Jersey State Highway Department, a position he had held since 1925. Goodkind's technical aptness for bridge building was well proven by this point in his career. Among his many credits was the monumental "College Bridge" (since renamed the Morris Goodkind Bridge), built in 1929. This concrete multiple-arch structure carrying U.S. Route 1 over the Raritan River had won him awards and national attention. Goodkind's career is described below in detail. An average of 65 employees worked under Goodkind, including 12 bridge designers, seven bridge detailers, five resident engineers, three draftsman, 32 bridge inspectors, and several administrative personnel (New Jersey State Highway Department 1940:n.p.). Goodkind was directly assisted in the preparation of the plans and drawings for the Edison Bridge by bridge designer W.F. Hunter and chief draftsman L.C. Petersen. In addition to his in-house staff, Goodkind retained the services of the engineering firm of Ash, Howard, Needles and Tammen to review the design (Goodkind 1940b:631).

Construction of the bridge was divided into six separate contracts: the river piers, the river pier shafts, the south approach piers, the north approach piers, the structural steel, and the concrete deck and lighting systems. The first contract to be awarded was for the construction of the river piers, which went to the Peter F. Connolly Company in the amount of $1,157,657, roughly $24,000 less than the design estimate. Connolly began work on September 26, 1938, and by the end of the year 10 percent of the work was completed. Connolly subcontracted part of the work to the H.J. Deutschbein Company (*Engineering News-Record* 1940a:61; New Jersey State Highway Department 1938:n.p.).

Noncontract work on the bridge had actually begun in May 1938 with the grading and filling of the marshy area between the future bridge and Victory Circle that would be the south approach. The Highway Department performed the work, using laborers hired under the department's PWA program. The work was completed in the spring of 1939 (New Jersey State Highway Department 1939:n.p.).

The Peter F. Connolly Company also won the contract for the pier shafts, with a bid of $358,598. Although this amount was roughly $90,000 more than the design estimate, Connolly still came in with the lowest bid, not uncommon for a contractor who has the advantage of having his equipment and labor already effectively working on the job. With several of the river piers completed, Connolly began work on the shafts on August 28, 1939 (New Jersey State Highway Department 1938:n.p.).

On the basis of subsurface conditions and the structural requirements of the tall slender concrete piers, foundations were designed as pneumatic caissons resting on solid rock at a depth of -60' to -90' MLW. The rock was overlain with sand and then 40' to 60' of mud. Because the river averaged only 6' deep at low tide, except in the main channel, there was insufficient depth for floating equipment. A 150' wide channel, 12' deep, was suction-dredged the entire width of the river (*Engineering News-Record* 1940a:58).

Construction of the 10 river piers and shafts required a complex arrangement of conventional as well as specially designed floating equipment. In order to deliver forms, steel, and concrete to the top of the tallest river piers, Connolly modified the 90' boom on his floating derrick by sliding a 100'-square steel tube over it to extend its reach to 150'. Cement was delivered by rail to a waterside track where a separate derrick boat transferred it to a floating barge. A screw conveyor and bucket elevator transferred the cement to the floating concrete plant, which mixed the batches and discharged the wet concrete onto a system of belt conveyors. Two thirds of the concrete for the pier shafts was placed using this system. A bottom-dump bucket, hoisted with the extended crane, placed the remainder. Connolly also developed a novel method for preassembling the steel reinforcing for the pier shafts' inside formwork, which was then lifted into place by the tall crane (*Engineering News-Record* 1940a:60).

The Peter F. Connolly Company completed its work on the piers and the pier shafts on June 28, 1940, and the following month the contractor's work was featured in an article entitled "Unusual Equipment Speeds Caissons and Piers" which appeared in the journal *Engineering News-Record* (*Engineering News-Record* 1940a:60; New Jersey State Highway Department 1938:n.p.).

Because the foundations for the approach piers were in shallow water, they did not require pressurized caissons and underwater work. Since construction using open cofferdams and conventional pile driving methods is less specialized, and hence more competitive, the construction of the approach piers was bid separately. The contract for the south approach piers was awarded to the Folhaber Pile Company for $184,471, which was $108,000 less than the design estimate. The contract for the north approach piers was awarded to the J.F. Chapman Company for $217,182, which $61,000 less than the design estimate. Folhaber began work on March 21, 1939, and completed it on December 7, 1939. Chapman began work on April 24, 1939, and finished it on October 23, 1939. Although the contract prices looked like a good deal for the state, with bids well below estimates, both companies had severely underbid the work. Upon completion of the contracts, Folhaber was paid an adjusted price of $227,166 and Chapman an adjusted price of $219,581 (Goodkind 1940b:629; New Jersey State Highway Department 1939:n.p.).

The project included the construction of two identical concrete-encased deck girder overpasses above the Victory Circle in South Amboy. These two bridges, No. 1209154 and No. 1209153, were built by the Eisenberg Construction Company at an average cost of $35,000 apiece. Work began in January 1940 and was completed in July of the same year (New Jersey State Highway Department 1940).

The contract for the supply and erection of the structural steel on the Edison Bridge was awarded to the Bethlehem Steel Company in the amount of $1,708,820, which was $70,000 more than the design estimate. Work began September 1, 1939, and was completed December 14, 1940, for an adjusted price $5,500 less than the contract price (New Jersey State Highway Department 1940:n.p.).

The fabrication, shipment, final assembly, and erection of the bridge girders involved many unusual problems due to their unprecedented weight, length, and depth. The steel girders were fabricated at Bethlehem Steel's Pottstown, Pennsylvania, plant and shipped by rail to Jersey City, where they were loaded onto car float barges for delivery by water to the bridge site. The 85', 134', and 154' girders were fabricated and shipped in one piece. Shipment of the 154' girders (15'-2" deep) required the building of special railcars. During shipment to Jersey City by diesel locomotive, the girders cleared the rail by 4½" and the overhead electrification lines by 5", requiring shutdown of power to the system (Goodkind 1940b:626).

The 600' and 650' continuous girders were completely assembled at the plant and then disassembled into sections to enable shipment by rail. The 600' girders were fabricated and shipped in six 100' sections. The 21' depth of the 650' girder was too big for shipment and required a horizontal field splice in the haunch. The seven sections comprising the 650' girder were field spliced at the construction site to form three sections consisting of a 260' section weighing 198 tons, a 247' section weighing 179 tons, and a 143' section weighing 97 tons (Goodkind 1940b:630-631).

C.L. Lane, assistant manager of erection for Bethlehem Steel Company, supervised the erection of the superstructure. The first step was the placing of the six 85' approach spans at the north end of the bridge. These were erected from the ground by a 72' crane and presented no problems. A traveling crane, or "traveler," with two 85-ton stiff-leg derricks with a combined lift of 125 tons, was then lifted and erected in place on the approach girders using a 110' crane. The traveler weighed 260 tons, was powered by a 300 horsepower engine, and was equipped with four railcar trucks to roll on rails laid directly on the girders. Once assembled on the bridge girders, the traveler was then rolled out to the end of the north approach spans to Pier 6N and positioned to begin erecting the 156' spans out to Pier 10. While work progressed setting the 156' girders, an 85-ton traveling crane was used to place the 134' girders of the south approach (Goodkind 1940b:629-631).

The erection of the three sections of the 650' girder required the design and construction of one of the world's largest floating bridge erection derricks. The unit consisted of a 77' boom extending from an 86' tower mounted on a 120' by 72' sectional barge. This derrick was assisted in the record-setting lift of the 260' girder by the 125-ton capacity traveler (Goodkind 1940b:629).

To prevent bending in the girder during the lift, a horizontal stiffening truss was attached to the girder and remained in place until the girder pairs were joined together with floor beams. The double-intersecting truss consisted of four 22'-long outrigger 1-beams, with a 1"-diameter cable stretched around the ends of the beams and attached to the ends of the girder to act as the chord member (Hunt 1941:106).

The 260' girders could not be lifted into place if there was the slightest wind; bad weather resulted in numerous delays. The first girder was successfully lifted into place on the morning of March 14, 1940, establishing the new heavy-lift record. The bracing system functioned perfectly. Several hours later, during the lift of the second girder, its bracing system failed and the top flange buckled approximately 3' out of alignment. The girder was lowered to the barge and after several days of work was successfully straightened and determined suitable for use. With additional cable members added to the erection bracing truss, the second girder was lifted into place without further incident on March 18 (*Engineering News-Record* 1940b:11; *Perth Amboy Evening News* 1940b:21).

The final work contract was for the concrete deck and lighting and was awarded to the John G. English and Joseph Nesto Company in the amount of $283,081, which was $132,000 less than the design estimate. Work began March 1, 1940, and was completed December 23, 1940, for an adjusted contract price of $329,049. The contractor filed a claim for additional compensation based on delays in the work schedule. The outcome of the claim was not determined in the course of research (New Jersey State Highway Department 1938:n.p.).

Part of the lighting contract included the installation of an overhead lane-control system which used red and green lights to control traffic in each lane. The center lane travel direction could be reversed to add a third lane to the prevailing flow, which at the time the bridge was built was southbound in the morning and northbound in the evening. These light have since been removed. It was not determined how unique or innovative this use of lane-control lights was at the time (Goodkind 1940a:492).

The bridge was originally scheduled for opening on June 29, 1940, but long before that date was reached it became apparent that the structure was far from complete. The placement of the concrete deck and the painting of the steel superstructure continued through the summer, while motorists suffered another season of traffic delays on the Victory Bridge. When the bridge appeared complete enough for the workers' vehicles to pass back and forth, Mayor John Delaney of Perth Amboy, Mayor William Chevallier of Sayreville, and Mayor August Greiner of Woodbridge lobbied the highway department to open the bridge on weekends to help relieve the traffic. Their efforts were successful and on Friday, October 11, the three mayors met at the center of the bridge to congratulate one another and "open" the bridge to weekend traffic. Meanwhile, painting and electrical work continued (*Perth Amboy Evening News* 1940b:1).

On November 20, 1940, the bridge was permanently opened to traffic, and State Highway Commissioner E. Donald Sterner announced that the dedication would be held on December 14. A protest and letter-writing campaign by some local officials did not succeed in convincing Governor Moore to postpone the ceremony until spring when a grand celebration could be planned and staged (*Perth Amboy Evening News* 1940c:1).

The bridge was officially dedicated at 1:30 p.m. on Saturday, December 14, 1940, with Mrs. Mina Edison Hughes, widow of the inventor, cutting a ribbon stretched across the roadway. About 500 people and a detachment of 650 soldiers from Fort Dix attended the dedication. In his dedication speech, State Highway Commissioner E. Donald Sterner declared that the bridge, situated in a state where one-third of the nations's key industries were located, was a vital link in the national defense program. Presiding over the ceremony was State Senator John E. Toolan. Also in attendance were Governor A. Harry Moore and Governor-elect Charles Edison, son of the inventor (*Perth Amboy Evening News* 1940e:1-2).

The final cost of the bridge was $4,696,000. More than 65,000 cubic yards of masonry, 50 percent buried from sight, went into the foundations, piers, and deck of the bridge. Over 2,500,000 pounds of reinforcing steel and 19,000,000 pounds of structural steel were used (*Perth Amboy Evening News* 1940b:21, 1940e:1). During the course of construction three workers were killed in falls from the bridge. Alex Zboyan, a carpenter from Perth Amboy, lost his footing while descending from the top of a river pier for lunch and plunged 125 feet into the river. Ira D. West, a steelworker from Keansburg, was the second casualty, falling 40 feet into the mire at the south end of the bridge. West was standing on a girder when he lost his footing while reaching for a cable. John Wright, a steel worker from New York City, fell 130 feet into the river (*Perth Amboy Evening News* 1940d:19).

Continuous Plate Girder Bridges

The Edison Bridge is historically important because it is a very large and early example of its type. The bridge marks an important step in the development years of the modern continuous deck girder highway bridge, a period which began in about 1932 and culminated in the early 1940s with the construction of several monumental bridges, the Edison Bridge included.

When completed, the Edison Bridge not only exceeded common engineering practice, but set a new record for its type and a new record in bridge erection practice. It was the largest and highest continuous girder bridge in the U.S., and shared the record for longest girder span with a bridge in Charleston, West Virginia. (The Charleston bridge was begun after the Edison Bridge, but was completed sooner because it was much smaller overall.) The assembly and erection of the main-span girders of the Edison Bridge by the Bethlehem Steel Company involved the lifting of the world's longest (260') and heaviest (198 tons) girder to a height of 135'. Special train cars, barges, and cranes were constructed to transport and erect the girder.

A continuous bridge can be visualized as a single beam, supported at three or more points along its length. Trusses, plate girders, and box girders can be made continuous. The structural advantage over a simple span, which is supported only at its ends, results from bending forces created in the beam over the piers, which counteract and reduce the bending forces in the center of the span. The practical advantages are economy of material, convenience of erection in that no falsework is required, and increased rigidity under traffic. When the design was first put into use, some engineers believed that there were structural advantages to making more than three spans continuous, but it was later proven that no increase in rigidity was obtained with more than three spans (Lindenthal 1932:421; Skinner 1906:3).

A plate girder is I-shaped in section, "built up" or assembled with steel plates and shapes, 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 web of steel plate riveted or welded to parallel pairs of top and bottom flange angles. Typically, top and bottom flange cover plates and vertical web-stiffener angles at the ends and intermediate points are added for greater strength.

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 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 (Skinner 1906:3-4).

In explaining the popularity of plate girders, bridge engineer Frank Skinner states,

> 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 in to 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 [Skinner 1906:4].

Trusses were preferred for long spans for several reasons. Efficient use of material and therefore less cost is the mark of a good design, and on longer spans the waste represented by the excess material in the solid web became significant. Truss bridges could be assembled at the plant and disassembled for shipment, unlike girders, which could not be transported or handled in one piece much beyond

100' in length. 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.

Gustav Lindenthal contends that the continuous girder originated in Europe, with examples built for railroads in Germany, France, Switzerland, and Austria as far back as about 1835. According to technology historian Carl Condit, the first known continuous bridge was the Britannia Bridge in England, a four-span tubular plate girder bridge built in 1848. Several other continuous plate girder bridges were built in England in the mid-nineteenth century (Condit 1961:99; Lindenthal 1932:421).

The first continuous bridge in North America was the Lachine Bridge over the St. Lawrence River in New York State, a truss built in 1888 by C. Shaler Smith. The Lacine Bridge remained the sole example of a continuous truss on the continent until the 1917 construction of the record-setting twin 775'-span Sciotoville Bridge over the Ohio River by Gustav Lindenthal. Other engineers quickly adopted the continuous truss and many examples of the type soon followed (Hool and Kinne 1923:202; Lindenthal 1929:397).

> A detailed history of the early application of continuous plate girder bridges does not appear to have been compiled. According to Condit, the girder bridge, in both simple and continuous spans, was well developed before the end of the nineteenth century and has been used throughout the twentieth century for the great majority of short span railroad bridges, viaducts, and for metropolitan elevated lines. Such evolution as has occurred lay entirely in the constant extension of the length of individual spans and increasing refinement of the form, which reached an almost geometric purity in some of the highway bridges of the 1930's [Condit 1961:99].

Continuous girders also found application in steel-frame building construction where solid girders were extended over or were rigidly connected to columns. Textbooks on the principles of the continuous girder appeared at the end of the nineteenth century, but did not address the application of the girder to bridges (Howe 1889; Steiner 1895).

A review of the technical literature on early continuous plate girder highway bridges suggests that the form was developed, refined, and widely adopted within the span of a decade, beginning in about 1930. During the 1930s there was an increasing tendency toward the general use of continuous structures and other statically indeterminate forms. Engineers were gradually overcoming their fear of reversal stresses in continuous girders. This was principally due to the recent development of mechanical and photoelastic methods of checking stresses in celluloid, metal, or glass models of complex statically indeterminate structures. Models enabled the designers to visualize the behavior of every part of the structure under various conditions of loading, which gave confidence to analytical results and encouraged the use of indeterminate structures (Houk 1935:764).

As engineers gained a better understanding of the elastic properties of steel, it became apparent that adjustment of reactions for small settlements of the piers was unnecessary for continuous beam spans. The beams were found to be more limber than originally thought, and by locating the splices at or near points of zero dead load moments, the possibility of unknown moments or shears being locked up in them were eliminated (Ogden 1937:403).

Also during the 1930s, the deck-type bridge became the preferred form for highway bridges. With the dramatic increase in the number and speed of automobiles, the advantages of this type of bridge became more apparent to highway engineers. As opposed to a through bridge, a deck bridge provides an unobstructed view, creates less anxiety in the motorist from feeling hemmed in, and allows greater speed and safety because the optical illusion of a narrowing roadway is almost entirely eliminated (Ogden 1937:403).

Bridge engineers within state highway departments were chiefly responsible for the adoption of the continuous plate girder bridge form. The form was the most economical solution for most elevated and medium-span highway bridge applications, and the economic depression that was in progress demanded that new technologies which afforded safety and economy be courageously embraced. Perhaps the boldest and most aggressive highway department to adopt the new bridge form was in Kansas. Between 1933 and 1935 the highway department of that state designed and supervised the construction of over 50 continuous bridges, a large number of which were plate girders. Savings over simple-span structures were estimated between 10 to 30 percent, covering the increased engineering cost many times over. In addition to the savings in structural steel afforded by the design, a saving was realized by the elimination of expansion joints and a reduction in the number of rockers and bolsters. The greater rigidity reduced deflections by about 50 percent, which allowed shallower concrete deck construction. Additional savings were obtained by reducing the size of the pier caps, eliminating some end floor beams, and by increasing the economical span length of the plate girder (Lamb 1935:702-705).

Other state highway departments that were among the first to build continuous plate girder bridges, beginning in 1932 and 1933, and to publish descriptions of their results, include those of Georgia, Nebraska, and Montana (Bertwell 1933; Slack 1933; Sorkin 1933).

A landmark in the development of the modern long-span continuous plate girder bridge in the U.S. was the construction of the Capital Memorial Bridge in Frankfort, Kentucky, in 1937 by H.R. Creal, bridge engineer with the Kentucky State Department of Highways. The 200' main span was the longest continuous plate girder in the U.S., and with a depth of only 12' at the supports and 7' at mid-span, it achieved nearly the maximum theoretical slenderness ratio. With its gracefully curved bottom chords it also won the "most beautiful bridge of the year award" in its class from the American Institute of Steel Construction. Albeit more expensive to fabricate, curved bottom chords on deck plate girders decreased deflections on longer spans, and had the added benefit of providing a more pleasing appearance. This was the first plate girder bridge ever to win an aesthetic award.

Although the Institute's choice appears to be self-serving, considering the vast potential applications of the bridge form to super and elevated highways, it was selected by an impartial jury (Condit 1961:100; *Engineering News-Record* 1939a:39; Ogden 1937:403; Smith 1939:59-61).

Another development which spurred the use of continuous bridges was the publishing of *The Theory of Continuous Structures and Arches* by Charles M. Spofford in 1937. Spofford was a professor of engineering at the Massachusetts Institute of Technology. His highly acclaimed Lake Champlain Bridge (1929) and Cape Cod Canal Bridges (1935) established him, with Lindenthal, as a leader in the theory and practical application of continuous bridges (Spofford 1937:1, 2).

The year 1938 was a banner year for continuous plate girder bridges in the U. S., marked by a series of records set and broken in the length of continuous spans. The 200' span Capital Memorial Bridge in Kentucky was surpassed by the 217' span in Topeka, Kansas. Work commenced on a 220' span at Tallulah Falls, Georgia, and 250' spans at Charleston, West Virginia, and Perth Amboy, New Jersey. *Engineering News-Record* editorialized that the Perth Amboy bridge, which was not yet named the Thomas A. Edison Bridge, "will include eight 200' spans and will provide 135 foot shipping clearance, a layout which hardly would have been considered suitable for plate girders even a few years ago" (*Engineering News-Record* 1939b:66).

Although it shared the record span length with the Charleston Bridge, the Edison Bridge was of the monumental class (at the time, bridges costing over $1,000,000) and was "the first and only long high-level plate girder in the country" (*Engineering News-Record* 1941b:115). Other features of the Edison Bridge that put it in a class by itself, would not be surpassed for several years. The roadway was 52' wide and accommodated five lanes of traffic as compared with the two-lane Charleston Bridge. The much larger live and dead loads required a massively deep and heavy main-span girder, which, at 250' long and 21' deep over the supports, was "the maximum for this country" (*Engineering News-Record* 1941b:115).

In 1939 the widespread use of plate girders was considered the most notable development in steel bridge design. "Long span bridges, arch ribs, rigid frame bridges, viaduct bents and suspension bridge stiffening girders represent applications of the plate girder where heretofore the trussed member had almost exclusive reign" (Bowman 1940:74). In the same article, Bowman also notes that "it is becoming trite to say that continuous structures enjoyed increased popularity. Such a trend has been in evidence for a decade" (Bowman 1940:73).

The Edison Bridge held the record span length for a continuous plate girder bridge only six months. Cleveland's Main Avenue Bridge, begun in 1939 and completed in March 1941, set the new record in the U.S. at 271'. Although the bridge was also notable for its use of several all-welded rigid frames in the approaches, its camouflaged rockers, and the use of models to analyze the girder design, it did not approach the magnitude of the Edison Bridge (Bowman 1940:74; Plummer 1941:50).

The next major event in the development of the continuous plate girder bridge in the U.S. was the building of the Charter Oak Bridge over the Connecticut River at Hartford, begun in 1941 and completed in 1942. Upon completion, the Charter Oak Bridge would set a new record in the U.S., with an 840'-long continuous girder consisting of a main span of 300' flanked by 270' spans. During erection of the main span by the American Bridge Company, the bridge collapsed, dropping 470 tons of steel, a 176-ton traveling crane, and 32 workers and engineers 100' into the river. Sixteen men were killed. Professor Spofford of the Massachusetts Institute of Technology was appointed by Governor Hurley to investigate the collapse. The engineering community naturally focused great attention on the cause, and when it was shown conclusively that it lay in the erection methods and was not related to an "over bold design," and when the bridge was quickly completed and opened without further incident, the confidence and use of continuous plate girders that followed reached new heights. The completion of the Charter Oak Bridge not only established a new record, but also effectively marked the end of the development period of the modern long-span continuous plate girder highway bridge in America (*Engineering News-Record* 1941c:1-2; 1941d:52; 1942:72).

Morris Goodkind

Morris Goodkind was born in New York City in 1888 and graduated from Columbia University in 1910 with a degree in Civil Engineering. Following graduation, he worked with the City of New York Public Service Commission as a structural draftsman preparing plans for the city's subway system. After a year he moved to another city job as an instrument man on a survey team, which provided another year of experience in his field. In 1912, Goodkind left public service to join the private engineering firm of Albert Lucius as an assistant engineer. Albert Lucius (1844-1929) was a German engineer who had immigrated to the U.S. in 1865 and settled in New York. He designed the elevated railway systems for the cities of New York and Brooklyn, and in 1886 started a private consulting practice in New York City. Lucius specialized in bridges and designed several noted structures for railroad companies. Goodkind worked in Lucius's office between 1912 and 1914, and undoubtedly it was here that his interest and skills in bridge design were first honed (American Society of Civil Engineers 1930:1565-1566).

During his early career years Goodkind moved rapidly from job to job, gaining experience and jumping back and forth between the public and private sector. Between 1914 and 1918 he worked as a structural designer for the Interboro Rapid Transit Corporation. This was followed by a one-year stint with the J.G. White Engineering Corporation. In 1919 he went back to public service as bridge engineer for Mercer County, New Jersey. It would be 36 years before Goodkind would work again in the private sector (Downs 1948:751).

Goodkind joined the New Jersey Highway Department in 1922 as general supervisor of bridges and was named chief bridge engineer in 1925, a position he held until his retirement in 1955. He received numerous awards for his work over the course of his career with the state. His most prestigious award was the Phoebe Hobson Fowler Medal, given by the American Society of Civil

Engineers for his design of the College Bridge, a multi-span concrete arch carrying U.S. Route 1 over the Raritan River. This bridge has since been renamed the Morris Goodkind Memorial Bridge (Downs 1948:751).

Goodkind also won awards for the aesthetic design of his bridges, given annually by the American Institute of Steel Construction (AISC). The bridges designed by Goodkind that won "most architecturally beautiful bridge" of the year, in its category, were: the Oceanic Bridge over the Navesink River (1940); the Passaic River Bridge between Newark and Kearney (1941); and the Absecon Boulevard Bridge in Atlantic City (1946). The Cheesequake Creek Bridge on Route 35 between Sayreville and Madison (1943) won an honorable mention (*Engineering News-Record* 1941a:48; *New Brunswick Daily Home News* 1968:1, 12).

During World War II, Goodkind served as a consultant to the War Department, aiding the Army Corps of Engineers in the design and construction of bridges in the European Theater and elsewhere. While working in Washington during the war, he met a Chinese engineer at the YMCA where they were both staying. At the time, Goodkind and his fellow Corpsmen were in charge of designing bridges along the Burma Road, and were frustrated by their inability to get accurate Allied intelligence about suitable bridge sites. After hearing of the dilemma, the Chinese engineer pulled out a collection of detailed drawings, photographs, and notes of possible bridge sites, information which he had collected in a survey of the proposed Burma Road before the war (*New Brunswick Daily Home News* 1968:12).

Goodkind was awarded the Tau Beta Pi Achievement Certificate from Rutgers University in 1948, an honorary doctor of engineering degree from Newark College of Engineering in 1950, and the Egelston Medal from Columbia University in 1958—the highest award given by Columbia for engineering achievements. Following his retirement from the State Highway Department in 1955, he became a partner in the engineering firm of Goodkind and O'Dea, which remains in business today. Morris Goodkind died September 5, 1968 (*New York Times* 1968:8).

SOURCES OF INFORMATION/BIBLIOGRAPHY

A. Engineering Drawings:

There are approximately 50 sheets of microfilmed original engineering drawings of the Edison Bridge project on file under the heading "Route 35 Extension" at the New Jersey Department of Transportation, Trenton.

B. Historic Views:

A total of 249 black-and-white, 8x10" photographs and negatives depicting all aspects of the Edison Bridge construction are located at the New Jersey State Archives, Trenton. Record Group:

Department of Transportation, Photographs. Accession #: 1989.004, 1994.034. Box 2, Edison Bridge. A sampling of the collection has been included in this report.

C. Interviews: None

D. Bibliography

A.G. Lichtenstein & Associates, Inc.
n.d. *New Jersey Historic Bridge Survey, Draft.* Prepared for the Bureau of Environmental Analysis, New Jersey Department of Transportation. On file at the New Jersey Department of Transportation, Trenton.

American Society of Civil Engineers (ASCE)
1930 Memoir of Albert Lucius. *American Society of Civil Engineers Transactions,* vol. 94, pp. 1565-1566.

Bertwell, William
1933 Continuous Truss Utilized for Missouri River Bridge. *Engineering News-Record,* October 26, pp. 498-499.

Bowman, Waldo G.
1940 Bridges and Buildings. *Engineering News-Record,* February 15, pp. 73-76.

Condit, Carl W.
1961 *American Building Art, The Twentieth Century.* Oxford University Press, New York.

Downs, Winfred Scott (editor)
1948 *Who's Who in Engineering.* Lewis Historical Publishing Co., New York,

Engineering News
1888 The First Plate Girder in America. *Engineering News.* October 20, p. 305.

Engineering News-Record
1939a Annual Awards Made for Steel Bridges. *Engineering News-Record,* June 22, p.39.

1939b Civil Engineering and Construction in 1938. *Engineering News-Record,* February 2, pp. 59-67.

1940a Unusual Equipment Speeds Caissons and Piers. *Engineering News-Record,* July 4, pp. 58-61.

1940b Brief News: Largest Girder. *Engineering News-Record,* March 21, p. 11.

1941a Most Beautiful Steel Bridges. *Engineering News-Record,* May 22, p. 38.

1941b Bridges. *Engineering News-Record,* February 13, pp. 114-116.

1941c Falsework Suspected in Hartford Bridge Collapse. *Engineering News-Record,* December 11, pp.1-2.

1941d There's a Difference. *Engineering News-Record,* December 18, p.52.

1942 Hartford Bridge, with longest girder spans, opened. *Engineering News-Record,* September 10, p.72.

Goodkind, Morris
1940a Design Feature of Thomas A. Edison Bridge. *Civil Engineering,* August, pp. 491-494.

1940b Construction of Thomas A. Edison Bridge. *Civil Engineering,* October, pp.628-631.

Hool, George A., and W.S. Kinne (editors)
1923 *Movable and Long-Span Steel Bridges.* McGraw-Hill Book Co., New York.

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

Howe, Malverd A.
1889 *The Theory of the Continuous Girder.* Engineering News Publishing Company, New York.

Hunt, Hal W.
1941 Progress in Construction Practice. *Engineering News-Record,* February 13, pp. 105-107.

Lamb, George W.
1935 Continuous Spans Favored for Kansas Highways. *Engineering News-Record,* November 21, pp. 702-706.

Lindenthal, Gustav
1932 Bridges with Continuous Girders. *Civil Engineering,* July, pp. 421-424.

1929 Continuous Girder Bridges. *Engineering News-Record,* March 7, p. 397.

New Brunswick Daily Home News
1968 Morris Goodkind, Bridge Builder, Dies. *New Brunswick Daily Home News* September 7, pp.1, 12.

New Jersey State Highway Commission
1924 *Study of traffic on state highway Route No. 4, between Perth Amboy and Asbury Park: recommendations for relieving present traffic congestion and for providing adequate facilities for handling anticipated traffic: report of the Advisory Board to the New Jersey State Highway Commission.* MacCrellish and Quigley Co., Trenton. Available at New Jersey State Library, Trenton.

New Jersey State Highway Department
1935 *Annual Report of the New Jersey State Highway Department for the Year 1935.* New Jersey State Highway Department, Trenton.

1937 *Annual Report of the New Jersey State Highway Department for the Year 1937.* New Jersey State Highway Department, Trenton.

1938 *Annual Report of the New Jersey State Highway Department for the Year 1938.* New Jersey State Highway Department, Trenton.

1939 *Annual Report of the New Jersey State Highway Department for the Year 1939.* New Jersey State Highway Department, Trenton.

1940 *Annual Report of the New Jersey State Highway Department for the Year 1940.* New Jersey State Highway Department, Trenton.

New York Times
1968 Morris Goodkind, Engineer, 80, Dies. *New York Times,* September 7, p.8.

Ogden, C.W.
1937 The Modern Trend in Bridge Design. *Civil Engineering,* June, pp. 402-405.

Perth Amboy Evening News
1940a Early Ferries Were Popular. *Perth Amboy Evening News,* October 11, pp. 17, 20.

1940b Edison Bridge Opens Today for Weekend; "Ceremony" is Staged. *Perth Amboy Evening News,* October 11, pp. 1, 18, 21.

1940c Protest is Made Here On Date for Dedication of New Edison Bridge. *Perth Amboy Evening News*, November 27, p. 1.

1940d Three Were Killed Building Bridge. *Perth Amboy Evening News*, October 11, p. 19.

1940e Cuts Ribbon to Formally Open Edison Memorial Bridge. *Perth Amboy Evening News*, December 16, pp.1-2.

1946 Victory Bridge, a Vital Link. *Perth Amboy Evening News,* May 25, p. 3.

1959 River Key to City's Growth. *Perth Amboy Evening News,* June 22, p.1.

Plummer, Fred L.
1941 Girder Span Record Boosted to 271 Feet. *Engineering News-Record,* March 27, pp. 50-52.

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

Slack, Searcy B.
1933 Low Cost Highway Bridges. *Civil Engineering*, November, pp. 601-605.

Smith, E.D.
1939 Building a Beautiful Bridge. *Engineering News-Record,* December 21, pp. 59-61.

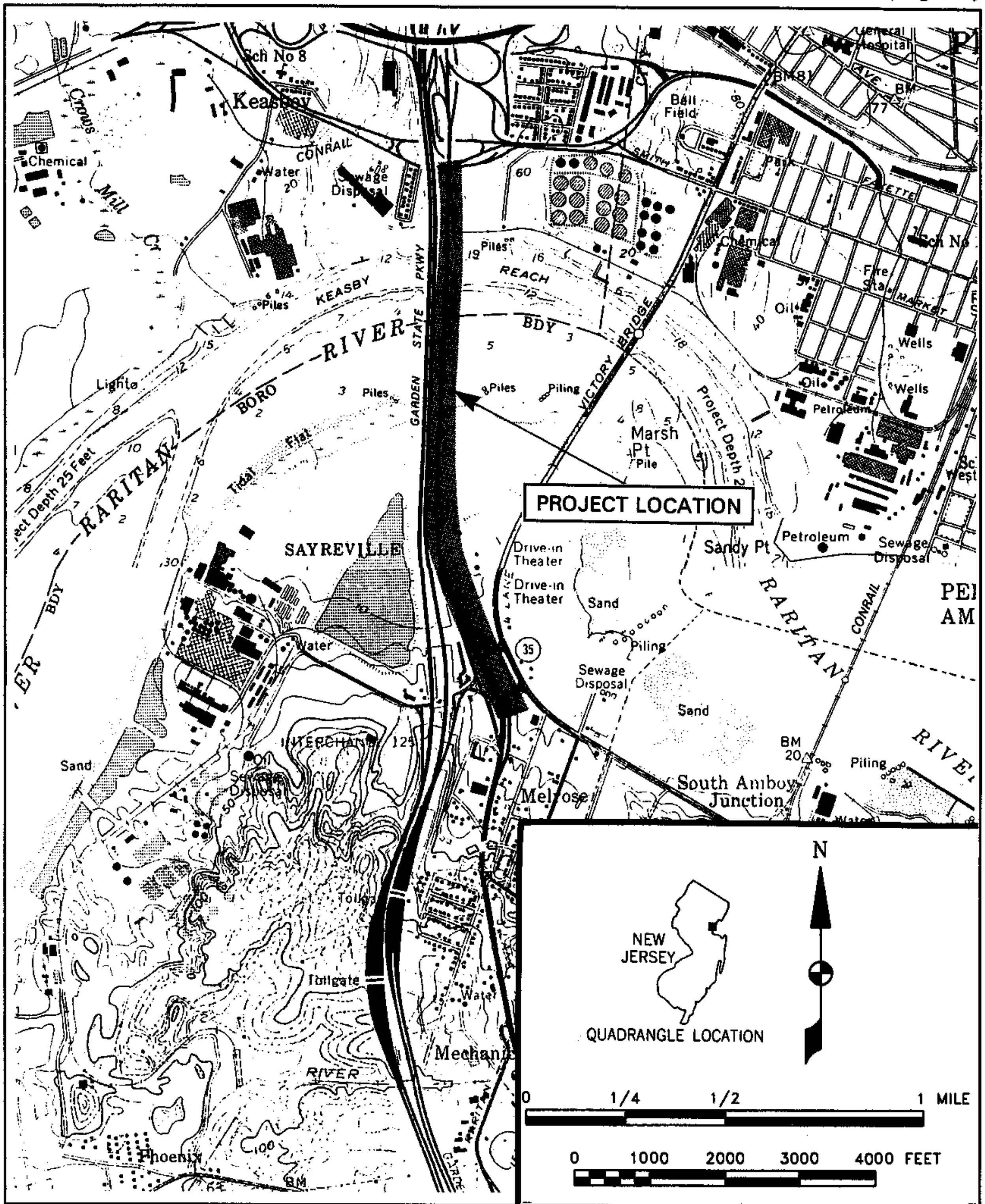
Sorkin, Josef
1933 Economy Through Continuity in Girder-Beam Bridges. *Engineering News-Record,* October 26, pp. 496-498.

Spofford, Charles M.
1937 *The Theory of Continuous Structures and Arches.* McGraw-Hill Book Company, Inc., New York.

Steiner, Charles
1895 *The Theory of Elasticity Applied to a System of Continuous Girders and Columns.* Published by author, Elmira, New York.

E. Likely Sources Not Yet Investigated: None known.

F. Supplemental Material: None included.



Location Map

SOURCE: USGS 7.5 Minute NJ-NY Quadrangles, Perth Amboy, South Amboy