HISTORIC AMERICAN ENGINEERING RECORD

Addendum to
GOETHALS BRIDGE

HAER No. NY-305

Location: Spanning the Arthur Kill at Interstate 278, south of Trenton Avenue, City of Elizabeth, Union County, New Jersey, and south of Western Avenue, Staten Island, Richmond County, New York. The original HAER documentation for the Goethals Bridge identified its location with the phrase "connects Staten Island with Northern New Jersey." This has been modified in the current submission to "spanning Arthur Kill from New Jersey to Staten Island."

The Goethals Bridge is located at latitude: 40.636, longitude: -74.197. The coordinate represents the centermost point of the bridge's main span. This coordinate was obtained on March 11, 2014 by plotting its location on the Elizabeth, NJ-NY USGS Digital Raster Graphic in ESRI ArcGIS 10.2. The accuracy of the coordinates is +/- 12 meters. The coordinate datum is North American Datum 1983.

Present Owner: Port Authority of New York and New Jersey (PANYNJ)

Present Use: Highway Bridge

Significance: The Goethals Bridge was one of the first two links for vehicular traffic between Staten Island, New York, and New Jersey. The bridge was designed and built simultaneously with the Outerbridge Crossing, between Perth Amboy, New Jersey and Tottenville, New York. The twin bridges were one component in a comprehensive plan to unify the Ports of New York and New Jersey and to reduce the strain on the regional ferry system. The cantilever steel truss bridge is significant for its engineering and design, specifically the innovative paving and pier construction methods utilized. Due to variations in ground conditions, three different methods were used to dig the pier foundations in and around the Arthur Kill. Wood and steel sheetpiling was used for the approach piers; open cofferdams were used for three of the channel piers; and a pneumatic caisson was used for Pier C, the main channel pier on the New York side.

Historian: Lynn M. Alpert, February 2014

Project Information: Recording of the Goethals Bridge was completed in 2014 by Richard Grubb & Associates, Inc. (RGA) for Kiewit-Weeks-Massman (KWM, Paul Beljan, Project Director) under contract to the PANYNJ. It was conducted under the general direction of Catherine Turton, HABS/HAER

Coordinator for the National Park Service (NPS). Damon Tvaryanas, RGA Senior Historian, supervised the project. Photographer Joseph Elliott prepared the photographic documentation. RGA Architectural Historian Lynn M. Alpert prepared the historical report. Kenneth Hess at Parsons Transportation Group coordinated the overall historical compliance for the project.

Part I. Historical Information

A. Physical History:

1. Date of Construction: 1926-28[1]

2. Designer/Engineer: John Alexander Low Waddell, engineer and founder of Waddell & Hardesty (now Hardesty & Hanover), designed the bridge. Shortridge Hardesty, engineer and co-founder of Waddell & Hardesty, acted as associate engineer for the design of the bridge.

3. Builder/Contractor: Frederick Snare Corporation built the substructure on the New York side of the bridge, under the supervision of Randall Cremer, Contractor's Engineer. Triest Contracting Corporation built the substructure on the New Jersey side. The Bethlehem Steel Company fabricated and erected the superstructure, under the supervision of W.A. Hazard, the Contractor's Engineer. The Contractor's Engineer for Triest Contracting Company is not known. C. M. Rauterkus served as superintendent for Triest Contracting Company, and D. H. Cameron served as superintendant for Frederick Snare Corporation.[2]

4. Original plans and construction: In 1924, engineer John Alexander Low Waddell was hired by the Port of New York Authority (now the PANYNJ) to create preliminary designs for two bridges to connect Staten Island with New Jersey across the Arthur Kill.[3] The bridges, ultimately named the Goethals Bridge and the Outerbridge Crossing, were designed simultaneously and are almost identical, with slight variations due to differences in topography and breadth of the Arthur Kill at each site. The Goethals Bridge is a cantilever steel truss bridge with deck plate-girder approaches supported on reinforced-concrete arch piers.[4] Originally conceived as the Elizabeth-Howland Hook Bridge, it is the smaller of the two bridges, with a total length of 8,073'-0".[5]

The PANYNJ oversaw construction under the direction of John E. Ramsey, Chief Executive Officer, and Othmar H. Ammann, Bridge Engineer.[6] When completed, the Goethals Bridge utilized a total of 11,600 tons of steel and 82,000 cubic yards of concrete masonry.[7]

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[1] Port of New York Authority, *The Port of New York Authority Annual Report for the Calendar Year 1926* (Albany: J. B. Lyon Company, 1927), 7, and Port Authority of New York, *The Port of New York Authority Eighth Annual Report, December 31, 1928* (New York: Port of New York Authority, 1929), 8.
[2] "Building Substructure," 748.
[3] Othmar H. Ammann, "Highway Bridges to Connect New Jersey and Staten Island," *Engineering News-Record* 97, no. 9 (26 Aug. 1926): 346.
[4] "Skyscraper Piers Carry Two Bridges across Arthur Kill," *Construction Methods* 10, no. 8 (Aug. 1928): 24.
[5] Joe Mysak and Judith Schiffer, *Perpetual Motion: The Illustrated History of the Port Authority of New York and New Jersey* (Santa Monica: General Publishing Group, Inc., 1997), 48.
[6] Ammann, "Highway Bridges," 347.
[7] Mysak and Schiffer, *Perpetual Motion*, 48.

5. Alterations and additions: In 1954, the approaches on the New Jersey side of the bridge were modified to include two new approach lanes. The lanes were added to relieve increased congestion related to the 1952 opening of the New Jersey Turnpike (NJT).[8]

In 1955, outer edge concrete curb walls and steel guard rails were added, and the bridge was resurfaced.[9]

In 1964, plans commenced for the improvement of all three of the PANYNJ's Staten Island bridges: the Goethals Bridge, the Outerbridge Crossing, and the Bayonne Bridge, in preparation for the opening of the Verrazano-Narrows Bridge.[10] In 1964, the Goethals Bridge was resurfaced and the toll plaza on the New York side was replaced with a larger plaza.[11]

The improvement project continued in1965, with the construction of new administration and maintenance buildings for the PANYNJ adjacent to the new toll plaza and a new 1,200'-long eastbound approach on the New Jersey side of the bridge.[12] The new eastbound approach ramp merged with the existing approach structure to the east of the NJT, and the existing approach structure was dedicated to westbound traffic only.[13] Alterations to the original New Jersey approach also included modifications of superstructure framing and piers over the NJT right-of-way, related to NJT improvements taking place at that time.[14]

In 1966, two eastbound on-ramps were constructed on the New Jersey side of the bridge. Both were constructed to carry eastbound I-278 traffic over westbound I-278 traffic.[15] Around this time, new barrier curbs were installed. Set back 0'-9" from each of the two original sidewalk curbs, the 1'-6"-tall, reinforced-concrete barrier curbs reduced the total width of each sidewalk to 3'-4".[16]

In 1972, a median concrete barrier was installed extending the full length of the bridge.[17] A new traffic control system also was installed on the bridge and approaches at this time.[18]

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[8] "Span Traffic Relief Due: Approaches to Goethals Bridge to Be Revised in August," *New York Times*, August 1, 1954, http://www.proquest.com, and "Contracts Awarded by Port Authority," *New York Times*, October 17, 1954, http://www.proquest.com.
[9] "To Improve Staten Island Spans," *New York Times*, August 12, 1955, http://www.proquest.com.
[10] "Jersey Spans Resurfaced and Approaches Widened," *New York Times*, October 24, 1964, http://www.proquest.com, and "Goethals Bridge Approach In Jersey to Be Improved," *New York Times*, December 11, 1964, http://www.proquest.com.
[11] "Jersey Spans," and "Goethals Bridge Approach."
[12] "Jersey Spans," and "Goethals Bridge Approach."
[13] *Historic Bridge Alternatives Analysis for Goethals Bridge Replacement*, Goethals Bridge Replacement Environmental Impact Statement (Morristown, NJ: Louis Berger Group/PB Joint Venture, 2008), 15, http://www.panynj.gov/goethalseis.
[14] *Historic Bridge Alternatives Analysis*, 15.
[15] *Historic Bridge Alternatives Analysis*, 16.
[16] *Historic Bridge Alternatives Analysis*, 15.
[17] "Barrier Being Built on Goethals Bridge," *New York Times*, September 24, 1972, http://www.proquest.com.
[18] "Barrier Being Built."

B. Historical Context:

Staten Island Connections

Staten Island is separated from the mainland of New York and New Jersey by the Arthur Kill, the Kill van Kull, and Upper New York Bay. The name "Kill" is derived from the Dutch word *kil*, meaning "channel" or "creek."[19] Since the Colonial era, access to Staten Island has been gained primarily by crossing the kills on ferries. The first bridge from Elizabeth to Howland Hook was built by the British Army during the American Revolution, when General Howe utilized a pontoon bridge to move his troops out of New Jersey and onto Staten Island. The bridge was known as "belly bridge," because soldiers often had to duck or crawl across the bridge to avoid crossfire. It was destroyed after the war.[20]

Ferries began operating across the Arthur Kill at its narrowest point between Elizabethtown and Howland Hook in 1671.[21] A second ferry opened between Perth Amboy and present-day Tottenville in the early 1700s.[22] Stage coach routes connected to numerous ferry landings around the harbor. Routes over Staten Island offered a convenient stepping stone toward New York by crossing both the Arthur Kill and the Kill van Kull on their way to the short ferry trip between Jersey City and Manhattan.[23]

Despite the ferries, the island retained a remote feeling due to the overall lack of connections between Staten Island and the mainland of New Jersey and New York City. The disconnected state of the island continued throughout the nineteenth century.[24] Movement to improve Staten Island's connections began in the 1850s. At that time, local farmers wanted a bridge connection in order to more easily transport their produce to markets in New Jersey, but the demand was not great enough to advance the project.[25] In 1890, a bridge connection was built for Staten Island, the first since the belly bridge of the American Revolution. The 1890 crossing consisted of a railroad swing bridge constructed by the Baltimore & Ohio Railroad, in conjunction with the Staten Island Rapid Transit Railroad.[26] This would remain the only bridge connection to Staten Island for over 40 years.[27]

In 1898, the formerly independent municipalities of Brooklyn, Bronx, Queens and Richmond merged with Manhattan to create Greater New York. Within 12 years, three new bridges spanned the East River, and miles of new subway track stitched together the expanding city's farthest

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[19] Henry Petroski, *Engineers of Dreams: Great Bridge Builders and the Spanning of America* (New York: Alfred A. Knopf, 1995), 254.
[20] Sharon Reier, *The Bridges of New York* (New York: Quadrant Press, 1977), 109.
[21] Steven M. Richman, *The Bridges of New Jersey: Portraits of Garden State Crossings* (New Brunswick, NJ: Rutgers University Press, 2005), 100.
[22] Reier, *The Bridges of New York*, 109.
[23] Reier, *The Bridges of New York*, 109.
[24] Reier, *The Bridges of New York*, 109.
[25] Reier, *The Bridges of New York*, 109.
[26] Reier, *The Bridges of New York*, 110-111.
[27] Reier, *The Bridges of New York*, 110-111.

reaches. Only the Borough of Richmond, which comprised all of Staten Island, remained largely cut off from the rest of Greater New York, connected only by its network of ferries.

The Creation of the Port of New York Authority

Following the Revolutionary War, the adoption of the United States Constitution in 1787 left the New York Harbor controlled jointly by one federal government, two independent states, and numerous municipal authorities. This fact, combined with the port's peculiar location, gave rise in the nineteenth century to an elaborate transportation system made up of highways, canals, private railroads and water-born vessels of every description operating under multiple jurisdictions to deliver the nation's wealth to its most important commercial center. In 1824, a fight over the granting of exclusive steam ferry franchises in New York Harbor rose all the way to the United States Supreme Court. In its landmark ruling on Gibbons v. Ogden, the Court ruled that the Federal government, not New York or New Jersey, controlled interstate commerce, making New York a free port. Shortly after the ruling, dozens of ferry vessels plied the waters throughout New York Harbor.[28]

By the late nineteenth century, the shores of the Hudson River were so overrun with railroad facilities that latecomers to the New York market looked toward the shores of Staten Island for undeveloped water frontage.[29] By the turn of the twentieth century, the Port of New York was among the busiest ports of the world.[30] Numerous public and private efforts to organize the confusing and increasingly congested port operations, particularly under single management, met with only partial success, and true unification remained elusive.

A particularly contentious rate dispute between New York and New Jersey known as the New York Harbor Case (1916) highlighted the overwhelming scale and complexity of the problem. Ultimately the New York Harbor Case forced the Interstate Commerce Commission in Washington to conclude in 1918 that the Port of New York could only be treated as a single entity for the purposes of setting rates for goods arriving from either New York or New Jersey.

To resolve the port problem once and for all, both New York and New Jersey empanelled the New York and New Jersey Port and Harbor Development Commission, a special bi-state group, to study the port problem. Eugenius H. Outerbridge, chairman of the New York Chamber of Commerce, headed the group, while George Washington Goethals, fresh from his success in building the Panama Canal, served as consulting engineer.[31] In 1920, the Commission issued its findings. The report proposed a sweeping plan for comprehensive management of the port and called for the creation of a single organization to oversee the whole. The Port of New York

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[28] Wheaton J. Lane, *From Indian Trail to Iron Horse: Travel and Transportation in New Jersey, 1620-1860* (Princeton: Princeton University Press, 1939), 194.
[29] Reier, *The Bridges of New York,* 110.
[30] Mysak and Schiffer, *Perpetual Motion,* 31; Irving S. Kull, ed., *New Jersey: A History*, 3 vols. (New York: The American Historical Society, 1930), 1084.
[31] New York, New Jersey Port and Harbor Development Commission, *Joint Report With Comprehensive Plan and Recommendations* (Albany: J. B. Lyon Company, 1920), 1-3.

Authority was formed on April 25, 1921 by treaty between the states.[32] Anxious to see the fledgling authority connect their respective states, New Jersey Governor George S. Silzer and New York Governor Al Smith, backed by their respective legislatures, devised a simple plan with far-reaching consequences: charge the Port Authority with building four bridges across state lines: two highway bridges over the Arthur Kill at Elizabeth and Perth Amboy; one over the Kill van Kull at Bayonne; and one more, the most ambitious and most elusive to date, a span across the Hudson River for both vehicular and rapid transit traffic. The estimated price tag totaled $100 million.[33] Subsequently, the Goethals Bridge and Outerbridge Crossing were the first bridges completed by the Port of New York Authority (hereafter referenced by the present-day name of "PANYNJ").

As a young agency, the PANYNJ wanted to hire an established and experienced engineer to design the bridges. They believed that a well-known engineer would instill confidence in the public and, in turn, encourage the purchase of bonds, which were being sold to fund construction. For these reasons, the PANYNJ hired John Alexander Low Waddell, of the engineering firm of Waddell & Hardesty, to design both bridges.[34] Waddell was the founder of his firm and the author of several well-respected texts on bridge engineering.[35]

Waddell was aided in the design process by Professor William Burr of Columbia University's School of Engineering and by General George Goethals, former director of construction on the Panama Canal.[36] Though not directly involved with the original bridge designs, Othmar H. Ammann was named bridge engineer for the PANYNJ on July 1, 1925, and oversaw design and construction after that point.[37] The PANYNJ also stated in an annual report that they believed "emphatically that each bridge should combine beauty with stability and convenience." For this reason, the PANYNJ hired the architecture firm of York & Sawyer to oversee the architectural treatment of both bridges.[38] Some of the New York firm's other projects included the Bowery Savings Bank on East 42nd Street and the New-York Historical Society building.[39]

Waddell's designs for both of the bridges were completed early in 1925, followed immediately by a formal application to the War Department for permission to build.[40] Public hearings were also held at that time. The public voiced slight opposition to the Goethals Bridge, but most of the concerns at these hearings were related to the Outerbridge Crossing, primarily voiced by towing

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[32] New York, New Jersey Port and Harbor Development Commission, *Joint Report*, 1-3.
[33] Port of New York Authority, *The Port of New York Authority Annual Report for the Calendar Year 1927* (Albany: J. B. Lyon Company, 1928), 43.
[34] Petroski, *Engineers of Dreams*, 255.
[35] *Historic Resources Survey*, n.p.
[36] Reier, *The Bridges of New York*, 114.
[37] Petroski, *Engineers of Dreams*, 256.
[38] Port of New York Authority, *The Port of New York Authority Annual Report* (Albany: J. B. Lyon Company, 1926), 13.
[39] *Historic Resources Survey*, n.p.
[40] Port of New York Authority, *Annual Report* (1926), 19.

interests who worried that the proposed pier placement and bridge height would have negative impacts on navigation in the Kill.[41]

Despite these concerns on the part of the public, the PANYNJ believed the designs provided ample space for navigation, and on November 18, 1925, permits were received from the War Department to begin construction on both bridges. Work began on the final test borings, negotiations were opened with property owners whose land would be crossed by the bridge, including railroad companies, and conferences were held with city officials to finalize plans for the bridge approaches. At this point, detailed bridge plans were drawn up for the purpose of getting accurate cost estimates for the project.[42]

Construction began in October of 1926, and by December excavations on the approach piers had been completed and the foundation pilings had been driven. By the end of December, some concrete shafts were above ground-level.[43] On the New Jersey side, the excavations for the main channel pier had reached their final depth. On the New York side, the pneumatic caisson for the main channel pier was in position and work had started on the pouring of the foundations of the New York side piers as well.[44] The bridge's substructure was completed four months ahead of schedule. For this reason, the superstructure was also completed well ahead of schedule.[45]

The New Jersey and Staten Island sides of the bridge's central span were joined on December 6, 1927.[46] By the end of December, all of the bridge's steel had been erected and riveted. The Goethals Bridge superstructure was completed first, with some steel work left to be completed on the Outerbridge Crossing early in 1928.[47] Still, both bridges were completed nine months earlier than expected, and contractors were awarded a bonus of $400 for each day that they finished ahead of schedule.[48]

Dedication ceremonies for both bridges took place on the same day, June 20, 1928.[49] The Goethals Bridge was originally going to be named the Arthur Kill Bridge. Plans changed, though, when General George Goethals, first Chief Engineer of the PANYNJ, died suddenly just before the bridge's completion. For this reason the name of the bridge was changed in order to honor his memory. On June 29, the Goethals Bridge and Outerbridge Crossing opened as the

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[41] Port of New York Authority, *Annual Report* (1926), 19.
[42] Port of New York Authority, *Annual Report* (1926), 20.
[43] Port of New York Authority, *The Port of New York Authority Annual Report for the Calendar Year 1926* (Albany: J. B. Lyon Company, 1927), 54.
[44] Port of New York Authority, *Annual Report for the Calendar Year 1926*, 54.
[45] Port of New York Authority, *Annual Report for the Calendar Year 1927*, 44.
[46] Port of New York Authority, *Annual Report for the Calendar Year 1927*, 44.
[47] Port of New York Authority, *Annual Report for the Calendar Year 1927*, 44.
[48] Port of New York Authority, *The Port of New York Authority Eighth Annual Report, December 31, 1928* (New York: Port of New York Authority, 1929), 37.
[49] "Smith to Help Dedicate Staten Island Bridges Today," *New York Times*, June 20, 1928, http://www.proquest.com.

first vehicular bridge connections to Staten Island. Coincidentally, the date of opening the bridge to traffic was also General Goethals' birthday.[50]

Both bridges represented the overall expansion of New York's extensive highway and bridge network after World War I.[51] Still, the new connections did not immediately lead to population growth on Staten Island. Though the bridges supported the island's industries, it was not until the Verrazano-Narrows Bridge opened in 1964 that Staten Island's population truly expanded. The connection to New Jersey's mainland created by the Goethals Bridge and Outerbridge Crossing was important for industry, but a contiguous vehicular connection through Staten Island to the rest of the New York metropolitan area was essential for the expansion of the borough as a thriving residential community.[52]

The Goethals Bridge and Outerbridge Crossing are easily recognizable landmarks on the landscape of Staten Island, yet the significance of the Goethals Bridge does not entirely lie in its design. Despite the PANYNJ's decision to hire a well-known engineer to design the bridge, and an architecture firm to ensure the creation of a beautiful and notable structure, historians of bridge engineering have described the bridge design as undistinguished.[53]

Waddell worked under the general belief that design in America was less than impressive. He noted the lack of architectural training on the part of American engineers, which the PANYNJ attempted to remedy by hiring York & Sawyer.[54] Waddell also blamed the competitive bidding process used to choose engineers. He believed that the process created a demand for economical designs which greatly outweighed the importance of creativity, quality of materials, and aesthetic considerations in large-scale projects, thus leading to the creation of cheap and ugly bridges.[55] Despite this negative criticism, and Waddell's negative outlook, the Goethals Bridge and Outerbridge Crossing are important for the construction methods employed by the designers and builders involved. Additionally, they are significant for advancing the growth of the New York metropolitan area in the early twentieth century.

Construction Methods

The design for the Goethals Bridge called for a total of 75 reinforced-concrete arched support piers. Of these, four stood in the main channel of the Arthur Kill, while the remaining piers stood on dry land, 35 on the New Jersey, or West, approach and 36 on the New York, or east, approach. These "approach piers" were numbered 1W-35W and 1E-36E respectively. The four piers in the Arthur Kill, the "channel piers," were labeled west to east as Piers A, B, C, and D. The outer channel Piers, A and D, were often referred to as the "anchor piers" while the central

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[50] Reier, *The Bridges of New York*, 114.
[51] *Historic Resources Survey*, n.p.
[52] *Historic Resources Survey*, n.p.
[53] Petroski, *Engineers of Dreams*, 256; and Elizabeth B. Mock, *The Architecture of Bridges* (New York: Museum of Modern Art, 1949), 72.
[54] Reier, *The Bridges of New York*, 113.
[55] Reier, *The Bridges of New York*, 114.

two Piers, B and C, were called the “main channel piers.” The cantilever steel truss superstructure spans the Arthur Kill 1152' from Pier A to Pier D and comprises the structure’s “main crossing.” The main crossing consists of two “anchor spans” of 240', the first between Piers A and B, and the second between Piers C and D. The anchor spans are connected between Piers B and C by the 672-foot “central suspended span.”

A Warren truss system was employed for both bridges. The superstructure steel for the Goethals Bridge was fabricated and erected by the Bethlehem Steel Company, under the supervision of W. A. Hazard, Contractor’s Engineer.[56] The truss consisted of silicon steel, while the floor and bracing were of carbon steel.[57] In order to create a continuous web-like truss over the entire length of the bridge, each truss panel on the bridge was designed to be relatively equal, and relatively long when compared to bridges of that time, spanning between 40' and 42' each. The continuous truss extends over the bridge’s central suspended span and along both anchor spans without clear and purposeful visual breaks. This was not a common design method used for cantilever truss bridges at that time. More common were designs which visually expressed their specific engineering functions and points of transition between various functions in the structure’s form. This design provided the bridge with an aesthetic continuity not previously seen in cantilever truss construction, but it required the use of riveted flexible plate hangers inside of the posts, instead of the customary eye-bar hanger. The plate hangers were then pinned to the anchor arms and the central span. In this way, the design disguised the various load-bearing functions of the suspended span and anchor arms in relation to the trusses above, instead of placing an emphasis on them.[58]

The construction methods used for the piers and deck were remarkable for their time and discussed in multiple engineering magazines over the course of construction.[59] Though the design for all of the reinforced-concrete arched piers was the same, three different methods were used to sink the piers, due to the variety of ground conditions in and around the Arthur Kill.[60] Wood and steel sheetpiling was used for the approach piers; open cofferdams were used for three of the channel piers; and a pneumatic caisson was used for Pier C, the main channel pier on the New York side.[61] Contracts for substructure construction were awarded on July 29, 1926.[62] Triest Contracting Corporation fabricated the New Jersey approach piers and Frederick Snare Corporation fabricated the New York approach piers.

The primary method of excavation for the majority of the approach piers on both sides of the Arthur Kill utilized clamshell buckets operated by crawler cranes. Those piers located closer to the bulkhead line were excavated using stiff-leg derrick plants, and the four channel piers were

[56] “Skyscraper Piers,” 27.
[57] Harold Everett Wessman, “Design of Main Bridge Superstructures for the Arthur Kill Bridges” (master’s thesis, University of Illinois, 1929): 17-19.
[58] Wessman, “Design,” 17-19.
[59] See the bibliography for complete references to articles published in *Construction Methods* and *Engineering News-Record* between 1926 and 1928.
[60] “Building Substructure of Arthur Kill Bridges,” *Engineering News-Record* 99, no. 19 (10 Nov. 1927): 744.
[61] “Skyscraper Piers,” 25-26.
[62] “Skyscraper Piers,” 25.

excavated with orange-peel buckets operated on floating plants.[63] Pier concrete was mixed at commercial yards, located approximately a mile offsite, and delivered to the bridge by truck. Due to the swampy conditions on the New York side of the Arthur Kill, an onsite batching plant, which stood on offshore piles, was used to mix concrete for several of the New York approach piers. The plant was accessible by barge at both high and low tide, circumventing the need to bring the concrete mixing trucks into the wetlands.[64] Floating mixing plants were used to pour concrete for the four channel piers in the Arthur Kill.[65] Methods for pouring the concrete varied based on the height of each pier. Mixers poured the concrete directly for the lowest section of each pier. For the shortest piers, those at the far end of either approach, this was all that was necessary to complete an entire pier. To reach greater heights on the taller piers though, bottom-dump buckets were filled with concrete and lifted into the air by crane. Elevator masts were used to reach the uppermost portions of the tallest piers, which reached up to 160' in height.[66]

Borings that had been taken at Pier C consisted of “broken shale, sandstone, soft clay, and other materials that failed to core.”[67] Due to these complex conditions, the Frederick Snare Corporation did not know precisely how far down they would need to dig before they started work. As such, a pneumatic caisson was used at this pier. The wood caisson was 30' x 77' in plan and 75' high.[68] It was built at the Staten Island Shipbuilding Corporation and floated to the site, which had been dredged in preparation. It was assumed that the pneumatic caisson would require thirty-one pounds of air pressure, but due to the presence of dense clay overlying the rock, the contractor only needed to use eighteen pounds of air pressure.[69]

Though similar conditions existed at anchor Pier D, the presence of “a dense clay formation sloping up from the channel” meant that an open cofferdam could be used at this pier.[70] The clay formation made it easier to control the water, eliminating the need for a pneumatic caisson.[71] Still, due to the soft ground, extra heavy bracing was needed on the cofferdam, which consisted of three 12' x 12' frames erected above ground, with arch-web steel sheetpiling driven around each frame.[72] The steel sheetpiling was 1'-3" wide and 50'-0" long.[73]

A similar technique was used for approach Piers 1E through 17E, the seventeen New York approach piers closest to the Arthur Kill, though less heavy bracing was required. For these approach piers, 26'-long straight-web piling was used in combination with 6" x 12" wood planks.[74] At Piers 9E and 10E, which were sited on the bank of a small creek, the Frederick

[63] “Building Substructure,” 745.
[64] “Building Substructure,” 745; and “Skyscraper Piers,” 25.
[65] “Skyscraper Piers,” 25.
[66] “Skyscraper Piers,” 25.
[67] “Skyscraper Piers,” 25.
[68] “Skyscraper Piers,” 25.
[69] “Building Substructure,” 746.
[70] “Building Substructure,” 744.
[71] “Building Substructure,” 744.
[72] “Skyscraper Piers,” 25.
[73] “Skyscraper Piers,” 25.
[74] “Skyscraper Piers,” 25.

Snare Corporation drove the steel sheeting and wood pile supports into the ground before beginning any excavation work, and braces were used at these piers during excavation to keep the bottom of the steel sheeting from bulging in.[75] On the remaining New York approach piers, those located furthest from the channel, the Frederick Snare Corporation used 6" x 12" tongued-and-grooved wood sheeting in combination with 3" x 12" straight lumber.[76]

The borings taken for all of the piers on the New Jersey side found rock close to the surface. For Piers A and B, the New Jersey channel piers, cofferdams were used.[77] At Pier B, the main channel pier, the Triest Contracting Corporation fastened framing to old dock piles at the low water mark, with 10' columns placed above the framing and a second set of framing above that, creating a preliminary crib. Arch-web steel sheetpiling was driven around the crib, with bracing frames placed at 5' intervals. The Triest Contracting Corporation was able to remove the top 5' of rock with paving breakers, but the next 15' had to be blasted with 60 percent dynamite. The steel sheeting was then driven to rock, and 3" wood sheeting was placed below the steel to reduce the flow of water, while 3 steam centrifugal pumps removed any water that did manage to enter the cofferdam. As Pier B is sited on sloping ground, approximately 800 cubic yards of rock had to be placed on the east side of the cofferdam to equalize inward pressure.[78] The pier was carried 22' into the existing rock to protect against any future deepening of the ship channel.[79]

On the New Jersey approach piers, the Triest Contracting Company used 2" wood sheeting down to rock.[80] All of the foundation holes on this approach were between 24' and 50' deep. On the deepest holes, cross-bracing was used for added stability.[81] The Triest Contracting Company utilized air-operated clay spades to remove the shale at the New Jersey approach piers.[82]

To lay the bridge's concrete deck, paving contractors used vibrated forms and trap rock aggregates to create a slab that could withstand heavy traffic.[83] Two types of concrete slabs were utilized for the bridge: an all-trap-rock concrete slab, and a trap-rock-finish concrete slab.[84] A relatively dry mix was used, as the concrete's live load needed to test at 2,500 pounds after just twenty-eight days. The bridge also required a "particularly hard surface" in order to hold up against the constant and heavy use expected by the PANYNJ.[85] Due to the dryness of the concrete mixture, it was necessary to vibrate the forms with pneumatic hammers to ensure density and uniformity in the concrete slabs. [86] Albert A. Volk, Inc., of New York City, laid the

[75] "Building Substructure," 747.
[76] "Building Substructure," 747.
[77] "Building Substructure," 745.
[78] "Building Substructure," 746.
[79] "Building Substructure," 745.
[80] "Building Substructure," 745.
[81] "Building Substructure," 747.
[82] "Building Substructure," 747.
[83] "Arthur Kill Bridges Paved With Joggled and Vibrated Concrete," *Engineering News-Record* 101, no. 12 (20 Sep. 1928): 427.
[84] "Arthur Kill Bridges Paved," 427.
[85] "Arthur Kill Bridges Paved," 427.
[86] "Arthur Kill Bridges Paved," 427.

concrete on the majority of the bridge, both the main crossing and approach spans, and the Elizabeth Paving Company, of Elizabeth, laid the concrete for the bridge's east and west toll plazas.[87]

The all-trap-rock concrete slabs were the primary form of paving used for the spans in the main crossing, as well as most of the approach spans. Each all-trap-rock slab rested on longitudinal I-beams spaced 5'-4" apart.[88] Both wood and steel forms were used to lay the slabs.[89] The wood forms consisted of panels with 2" x 6" joists spaced 3' apart. Wire hangers, suspended from the I-beams, secured the joists at each end.[90] The steel forms consisted of 3'-6"-wide sections, long enough to span the I-beams. They were secured to the I-beams with 4 eccentric lugs clamped to the I-beam's upper flange. The forms were held in place with pins that extended through a slotted arm in the lug, allowing for easy removal of the forms.[91]

The all-trap-rock concrete was mixed in a central plant and delivered to the bridge by barge.[92] Workers utilized a traveling suspended working platform which provided 5' of headroom above. The platform was suspended from rollers engaged with two continuous I-beam rails which were clamped to the bridge beams and which sat low enough to clear the superstructure's cross-girders. The whole system was powered by an electric motor and generator.[93] Only half of the roadway width was paved at a time, to ensure that there was always room left for the track.[94] Due to the dryness of the mixture, the concrete did not flow easily from the chute into the form. The vibration method reduced rehandling of the concrete, encouraging the flow to travel under the reinforcing steel and reducing hand shoveling.[95] Jackhammers were used to vibrate the all-trap-rock slabs.[96]

Trap-rock-finish concrete was used in several approach spans. For this method, after the concrete was poured, the trap rock was spread by hand to create a top finish layer which was then vibrated into place. The trap-rock-finish slabs were of such a great density that they "could even be walked on while still wet with little effect."[97] Those slabs that were located on fill were poured with paving mixers.[98] Clay diggers were used for vibration of the trap-rock-finish slabs, which were found to be as effective as the jackhammers.[99]

[87] "Arthur Kill Bridges Paved," 429.
[88] "Arthur Kill Bridges Paved," 427.
[89] "Arthur Kill Bridges Paved," 427.
[90] "Arthur Kill Bridges Paved," 427.
[91] "Arthur Kill Bridges Paved," 427-428.
[92] "Arthur Kill Bridges Paved," 428.
[93] "Arthur Kill Bridges Paved," 428.
[94] "Arthur Kill Bridges Paved," 428.
[95] "Arthur Kill Bridges Paved," 428.
[96] "Arthur Kill Bridges Paved," 428.
[97] "Arthur Kill Bridges Paved," 428.
[98] "Arthur Kill Bridges Paved," 428-429.
[99] "Arthur Kill Bridges Paved," 428.

Part II. Structural/Design Information

A. General Statement:

1. Character: The Goethals Bridge is distinguished primarily by the construction methods employed for the bridge's piers. Due to variations in ground conditions, three different methods were used to dig the pier foundations in and around the Arthur Kill. Innovative paving methods were also utilized during the construction of the bridge. The superstructure of the main crossing consists of a continuous web-like Warren truss system of silicon steel. This design method, which lacked in purposeful visual breaks, was not common at the time of construction. Riveted flexible plate hangers inside of the posts, which were then pinned to the anchor arms and central span, had to be used instead of the customary eye-bar hanger. The resulting design disguised the various load-bearing functions of the suspended span and anchor arms in relation to the trusses above.

2. Condition of fabric: The main spans of the Goethals Bridge are in satisfactory condition, and the approaches are in good condition. The bridge exhibits some rusting of its steel members. The sidewalk slabs are in poor condition and are closed to pedestrian traffic. Multiple substructure piers exhibit some spalling and exposed rebar. The concrete deck slab is in fair to poor condition.[100]

B. Description:

The Goethals Bridge is a cantilever truss bridge carrying four lanes of traffic and two pedestrian sidewalks over the Arthur Kill.[101] The total width of the bridge is 62'-3".[102] With approaches, the total length of the bridge is approximately 11,825', and the elevated length, the portion of the bridge supported on piers, is 7,109', well over a mile. The bridge has a maximum grade of 4 percent.[103] The superstructure consists of a continuous Warren truss system of silicon steel.[104] Each truss panel is between 40' and 42' long, and the continuous truss extends over the bridge's central suspended span and along both cantilever arms without a visual break.[105] The bridge supports consist of reinforced, poured concrete. Each support is comprised of two sleek, stepped, buttressed piers joined by a central arch. The series of arched piers together are reminiscent of Roman viaduct design, though they are not oriented like a viaduct. The 1972 concrete median

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[100] Description of fabric conditions is based on field observations, as well as the conditions assessment provided in the 2004 Alternatives Analysis Report for the Goethals Bridge Replacement Project (*Historic Bridge Alternatives Analysis*, 19-22).
[101] Unless otherwise noted, the bridge description is based on field observations, as well as the technical information provided in the 2004 Alternatives Analysis Report for the Goethals Bridge Replacement Project (*Historic Bridge Alternatives Analysis*, 15-16).
[102] Mysak and Schiffer, *Perpetual Motion*, 48, and Reier, *The Bridges of New York*, 113.
[103] Reier, *The Bridges of New York*, 113.
[104] Wessman, "Design," 17.
[105] Wessman, "Design," 18-19.

barrier, which separates eastbound and westbound traffic, is 2'-8" high, 2'-0" wide at the base, 6" wide at the top, and extends 6,500'.[106]

The main crossing over the Arthur Kill consists of three sections: an east and a west anchor span and a central suspended span. The main crossing carries the continuous through truss superstructure over the river. The central suspended span measures 672'-0", and the total length of the main crossing is 1,152'-0" with a 135' clearance above mean high water.[107] Each anchor span is 240'-0" in length. Within the main crossing, each travel lane is approximately 10' wide, and each pedestrian walkway is approximately 5' wide. [108] The width of the Arthur Kill below the main crossing is approximately 500'.

The bridge's concrete deck slab, which is 9-½" thick, is supported by a floor system of built-up steel beams. In the anchor spans, the floorbeams are spaced 40' apart, while in the central suspended span they are spaced 42' apart. Between the centers of the truss chords, each floorbeam spans a distance of 47'. Thirteen rolled steel stringers span between the floorbeams, and two stringers span between the cantilevered extensions of the floorbeams and support each sidewalk.

The New Jersey (west) approach of the Goethals Bridge is comprised of thirty-five spans, numbered 1W through 35W, with a cumulative length of 2,831'. The New York (east) approach is comprised of thirty-seven spans, numbered 1W through 37W, with a cumulative length of 3,126'. The approach spans on the New Jersey side of the bridge are between 50' and 115'-6" in length, while the approach spans on the New York side of the bridge are between 57' and 112'. The standard deck framing of each approach span consists of two built-up deck girders. Built-up floorbeams span 32' between the deck girders, with a cantilevered segment at each fascia. There is from 14'-9" to 20'-0" of space between floorbeams. The approach sidewalks are 3'-4" wide and have a 1'-6"-high reinforced concrete barrier curb. The barrier curb was installed in the mid-1960s and stands 9" behind the existing curb on all approach spans.

The span framing differs where the New Jersey approach carries westbound traffic over Conrail, at Span 28W. Here the superstructure's built-up floorbeams span 47' between the through girders. There is approximately 5'-4" between each floorbeam. At approach spans 17W, 18W, and 19W, the superstructure steel is covered in a gunite encasement.

Where the New Jersey approach crosses the NJT, at spans 29W through 35W, the superstructure framing again differs from the norm. At this location, a ca. 1965 eastbound approach ramp merges with the original 1928 approach ramp, which has since been dedicated to westbound traffic. The piers, longitudinal fascia girders, and cross girders in this location all date to ca. 1965. The ca. 1965 superstructure consists of both welded I-deck girders with rolled floorbeams and four or five simply supported rolled stringers. In this location, the 1928 approach contains several pin and hanger assemblies.

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[106] "Barrier Being Built."
[107] Mysak and Schiffer, *Perpetual Motion,* 48.
[108] Mysak and Schiffer, *Perpetual Motion*, 48, and Reier, *The Bridges of New York,* 113.

The bridge has hollow abutments at both ends. The New Jersey abutment is 178' long, while the New York abutment is just 126' long. The substantially-larger New York abutment formerly contained a garage and other facilities spaces, but these areas are now vacant.

There are 2 eastbound on-ramps located to the west of the New Jersey hollow abutment. The first, called On-Ramp No. 6, is a 1966 on-ramp which carries eastbound I-278 over westbound I-278. The ramp is 117'-0" long and 34'-4" wide and consists of a 2-span, continuously supported, composite steel superstructure. The ramp has 5 cover plated, rolled steel stringers in each span. There are full height abutments located at each approach. The second ramp, called On-Ramp No. 7, is a 1966 on-ramp which was constructed for the same purpose as On-Ramp No. 6. On-Ramp No. 7 was never completed and is not in use. This ramp is 154' long and 28' wide with the same superstructure and stringer construction, with 4 stringers in each span. At this ramp there is a full height abutment to the south and 2 piers, but no north abutment.

The 1965 toll plaza, administration building, and maintenance building are located to the east of the New York hollow abutment. The administrative offices are located on either side of the toll plaza, and the upper stories of the administrative building connect above the toll booths. The maintenance building is located to the north of the toll plaza, on the opposite side of Goethals Road North. The buildings are connected by a second-story pedestrian skyway over Goethals Road North.

C. Site Information: The area surrounding the Goethals Bridge consists primarily of industrial sites intermixed with residential areas and wetlands. On the New York side, the bridge surroundings consist primarily of open wetland areas with several industrial sites interspersed throughout. On the New Jersey side, the industrial development is denser and includes a pocket of residential development, as well as the New Jersey Turnpike, which passes underneath the western end of the approach. The land underneath the New Jersey approach has a slightly higher elevation than that of the New York side, but the topography on both sides of the bridge is relatively flat.[109] This similar topography allows for the relative symmetry in the design of both approaches. The historic Staten Island Railway Lift Truss Bridge is located 600' north of the Goethals Bridge. The 1965 PANYNJ expanded toll plaza, administration building, and maintenance building are located approximately 1,250' southeast of the terminus of the New York approach. Two railroad lines, both now owned by Conrail, cross the Goethals Bridge. The tracks of the former Central Railroad of New York run from southwest to northeast through Elizabeth, parallel to the New Jersey Turnpike, and cross under the western terminus of the New Jersey approach. The tracks of the former Baltimore & Ohio Railroad run from northwest to southeast. They pass under the Goethals Bridge at bridge span 28W in New Jersey and cross the Arthur Kill via a railroad lift bridge to the north, continuing to the east through Staten Island.

[109] *Historic Bridge Alternatives Analysis for Goethals Bridge Replacement*, Goethals Bridge Replacement Environmental Impact Statement (Morristown, NJ: Louis Berger Group/PB Joint Venture, 2008), 4, http://www.panynj.gov/goethalseis.

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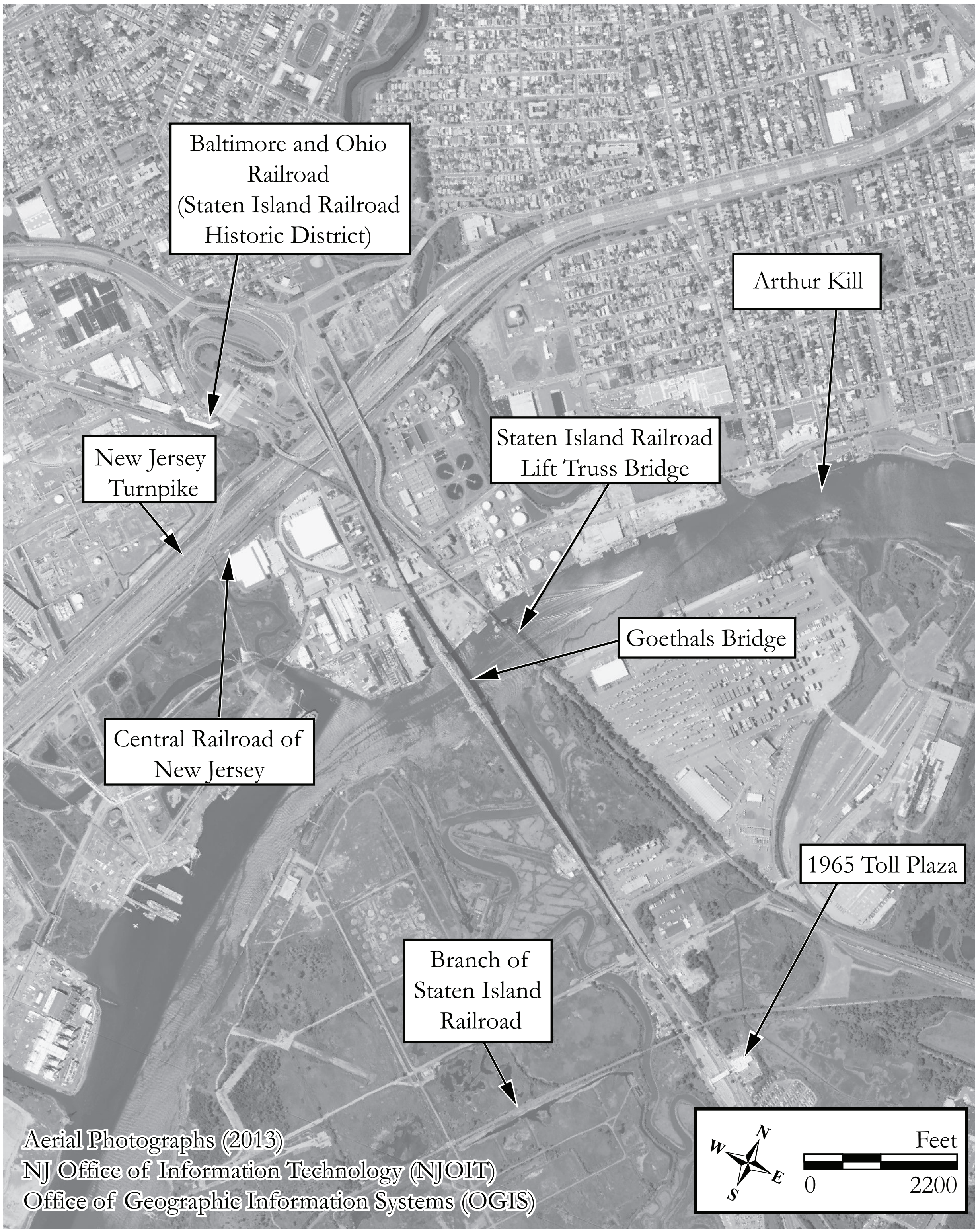
Appendix A. Site Plan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Arthur Kill
Staten Island Railroad Lift Truss Bridge
New Jersey Turnpike
Goethals Bridge
Central Railroad of New Jersey
1965 Toll Plaza
Branch of Staten Island Railroad
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GOETHALS BRIDGE — HAER No. NY-305
Spanning Arthur Kill from New Jersey to Staten Island
Staten Island
Richmond County
New York

Photograph numbers NY-305-1 through NY-305-7 were previously transmitted to the Library of Congress.

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Joseph Elliott, Photographer, February 2014

NY-305-8	Goethals Bridge from New Jersey side on a pier north of the Elizabeth River looking southwest. Railroad lift bridge in foreground.
NY-305-9	New Jersey approach and main crossing looking southeast. New Jersey Turnpike in foreground. From an access ramp near Relocated Bayway.
NY-305-10	New Jersey approach and main crossing looking southeast. From Relocated Bayway.
NY-305-11	Main crossing looking southeast. From South Front Street.
NY-305-12	Detail of New Jersey approach looking east. Railroad trestle in foreground. From Bayway Avenue.
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NY-305-15	New Jersey approach and main crossing looking east. Railroad lift bridge in background. Warehouse at right. From South Front Street.
NY-305-16	Detail of New Jersey approach substructure looking northwest. From Amboy Avenue.

NY-305-17	Detail of main crossing superstructure looking northeast. From roof of warehouse.
NY-305-18	Detail of main crossing, west anchor span, looking northeast. Railroad lift bridge in background. From roof of warehouse.
NY-305-19	Detail of main crossing, west anchor span and western portion of the central suspended span, looking northeast. Railroad lift bridge in background. From roof of warehouse.
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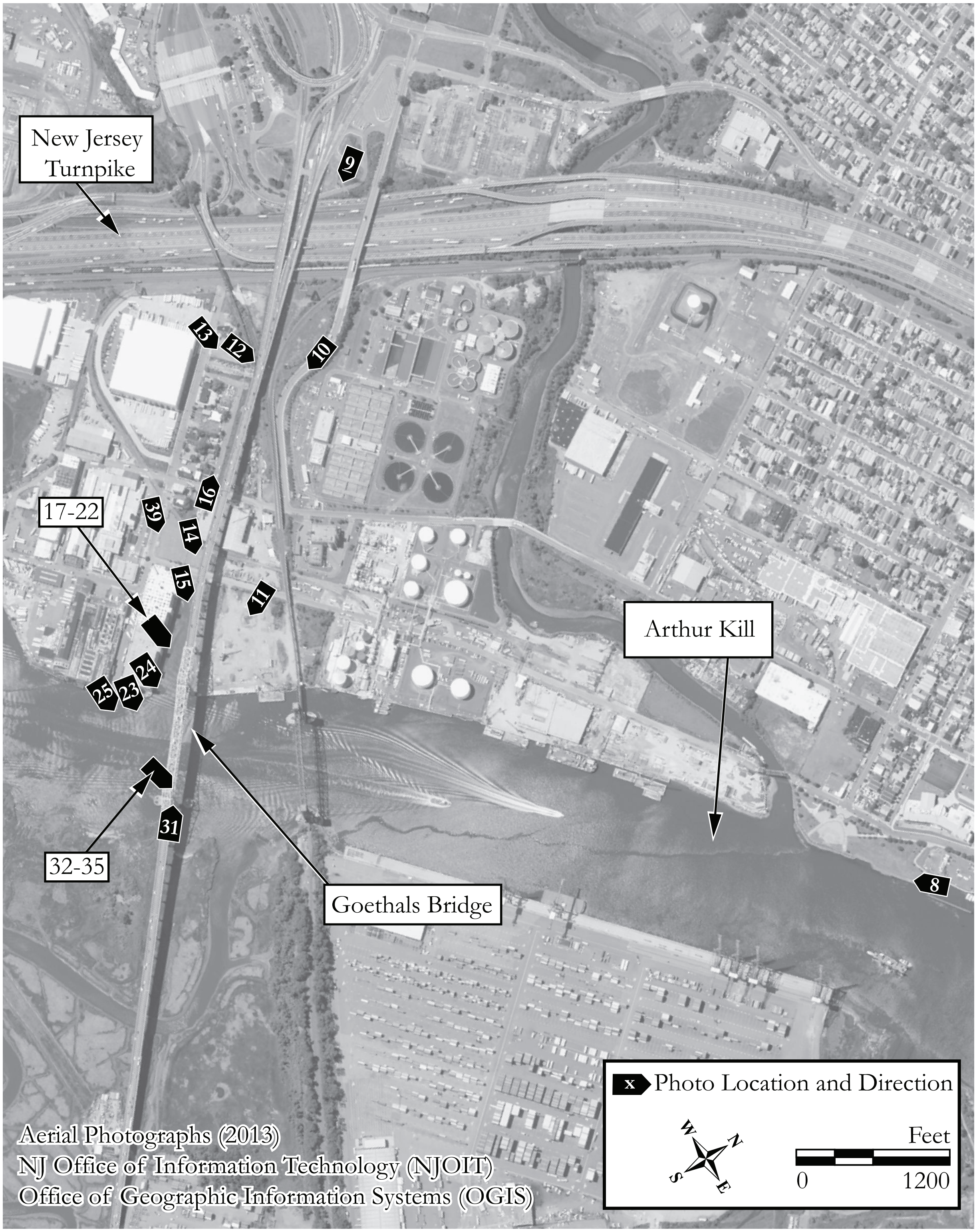
NY-305-21	Detail of main channel Pier B and superstructure above, where the west anchor span meets the central suspended span of the main crossing, looking northeast. From roof of warehouse.
NY-305-22	Detail of main channel Pier B looking northeast. From roof of warehouse.
NY-305-23	Central suspended span looking northeast. Warehouses at left. From water's edge near South Front Street.
NY-305-24	New York approach looking southeast. Eastern portion of the central suspended span and east anchor span in foreground. From roof of warehouse.
NY-305-25	New York approach looking southeast. Eastern portion of the central suspended span and east anchor span in foreground. From water's edge near South Front Street.
NY-305-26	Detail of New York approach substructure looking northwest. Approach Pier 16E in foreground. Near Goethals Road North.
NY-305-27	Detail of New York approach deck framing looking northwest. Near Goethals Road North.
NY-305-28	Detail of New York approach substructure looking northwest. Main crossing and New Jersey approach in background. Near Goethals Road North.
NY-305-29	Goethals Bridge looking northwest. New York approach at left and railroad lift bridge at right. Near Goethals Road North.

NY-305-30	Detail of New York hollow abutment and stairs leading to the pedestrian walkway looking northwest. Near Western Avenue.
NY-305-31	Detail of superstructure steel at the east end of the main crossing looking northwest. On southern pedestrian walkway, New York approach.
NY-305-32	Detail of superstructure steel above the east anchor span looking north. On the southern pedestrian walkway, main crossing.
NY-305-33	View northwest. Detail of superstructure steel above main channel Pier C. On the southern pedestrian walkway, main crossing.
NY-305-34	View north. Detail of superstructure steel above main channel Pier C. On the southern pedestrian walkway, main crossing.
NY-305-35	View northeast. Detail of superstructure steel riveting above main channel Pier C, with Manhattan skyline in background. On the southern pedestrian walkway, main crossing.
NY-305-36	View west. PANYNJ administration building and toll plaza. Near Goethals Road North.
NY-305-37	View northwest. Detail of PANYNJ administration building, with pedestrian walkway over Goethals Road North.
NY-305-38	View northeast. Detail of Goethals Bridge plaque at the entrance of the PANYNJ administration building.
NY-305-39	View southeast. Warehouse at Bayway and South Front Street with New Jersey approach and railroad lift bridge in background at left.

Appendix A. Site Plan with Locations of Photographs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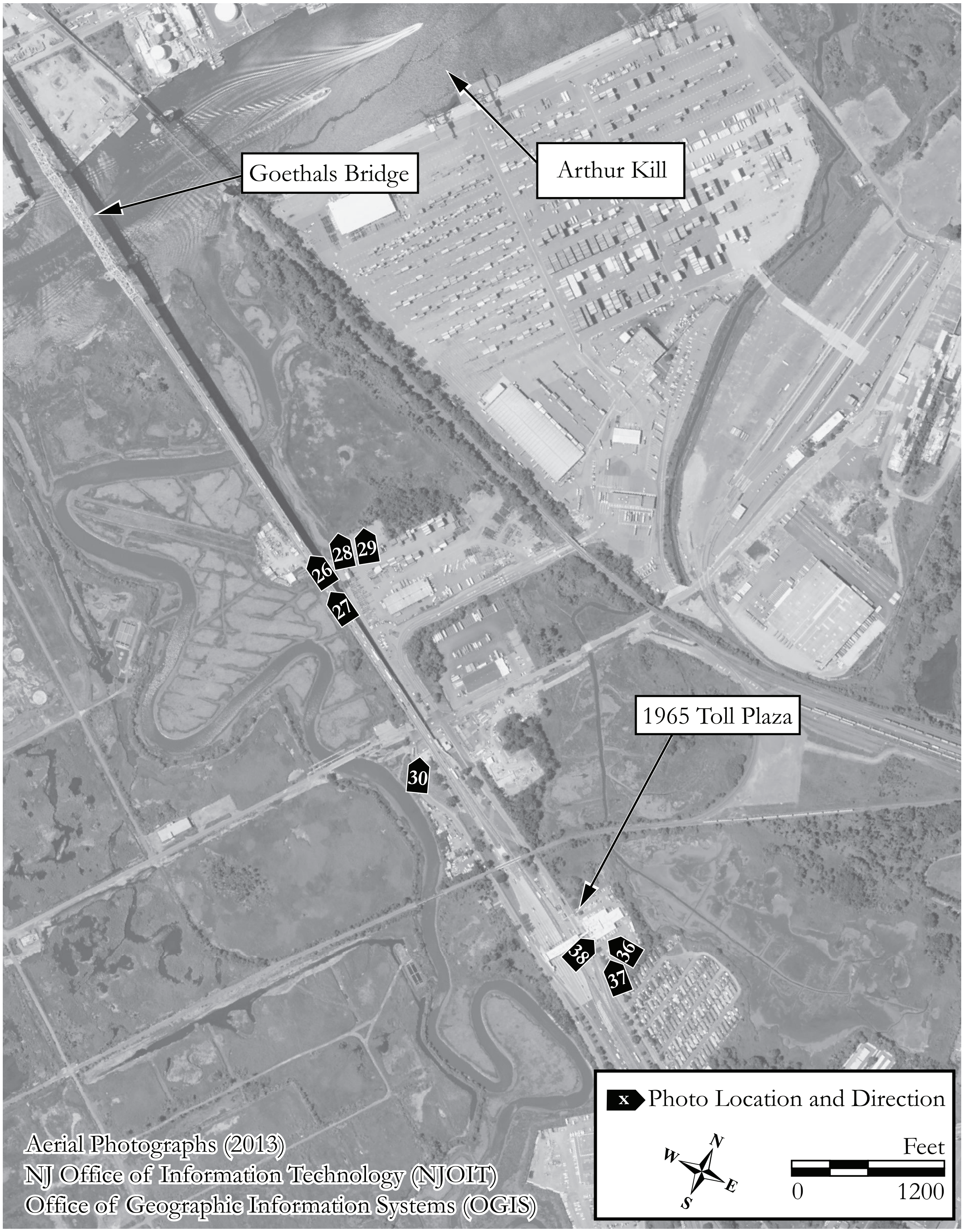
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Arthur Kill
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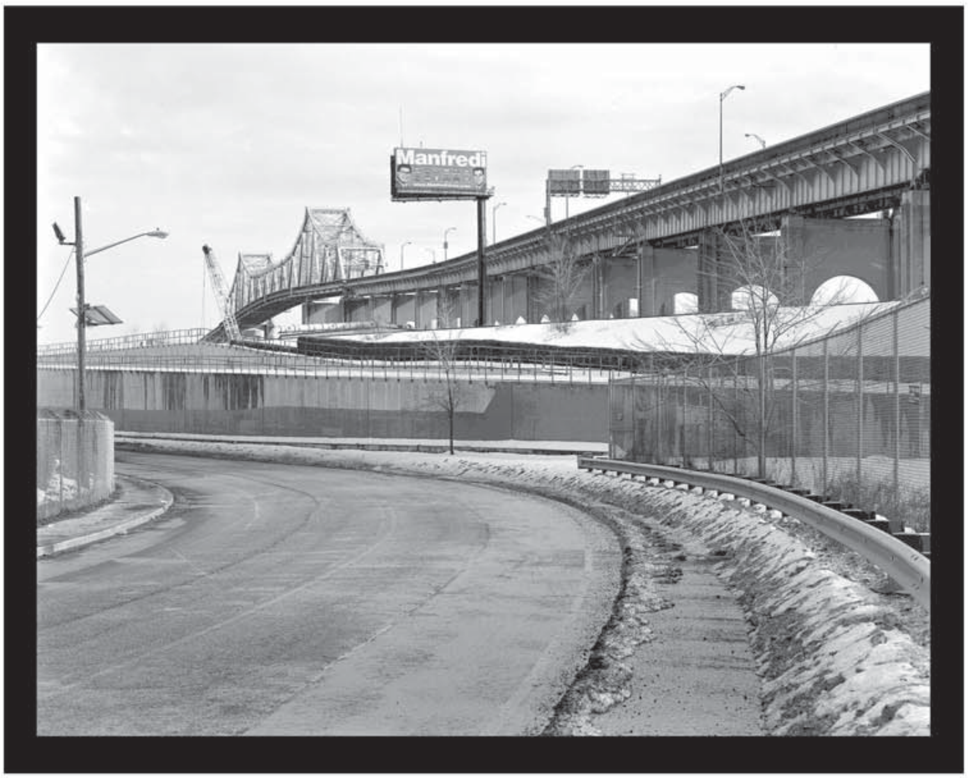

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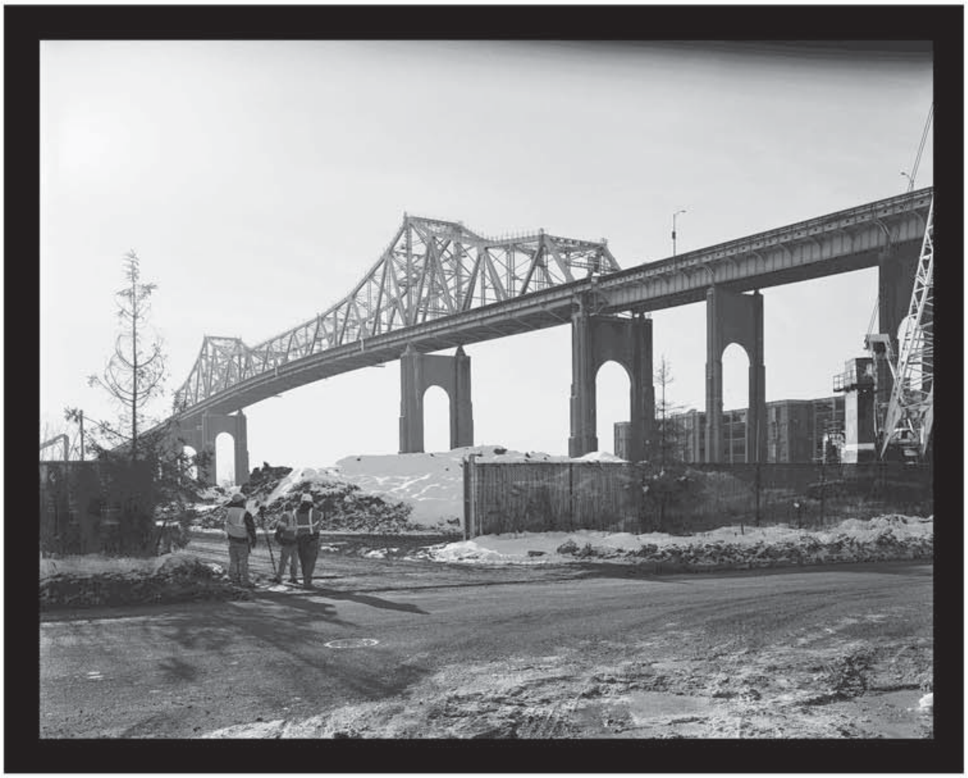

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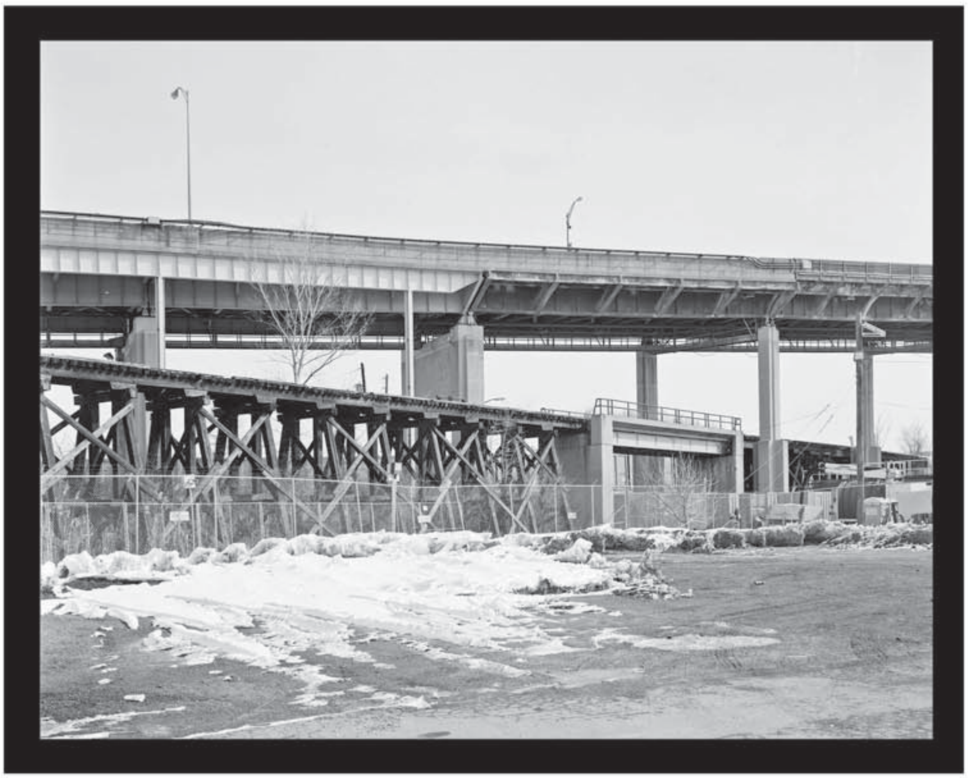

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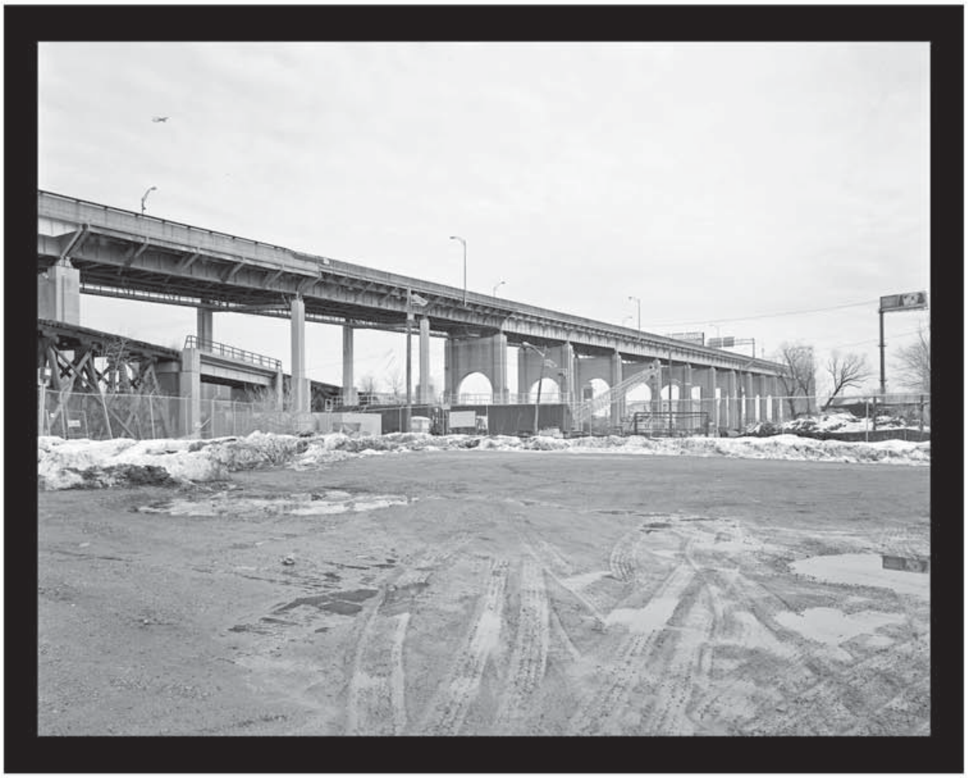

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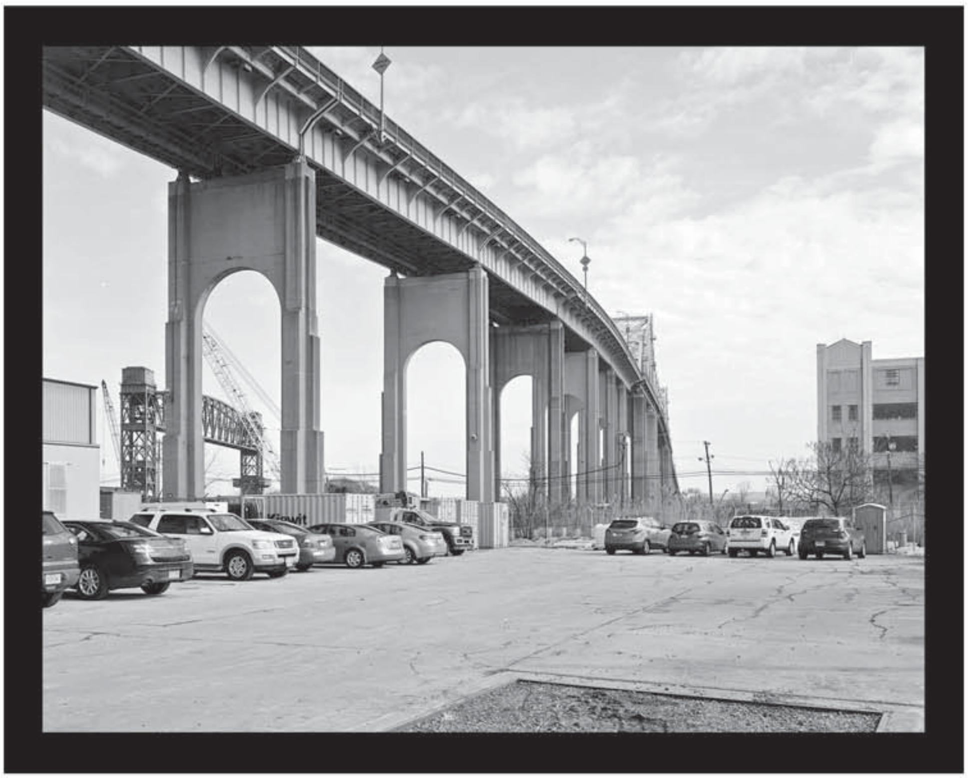

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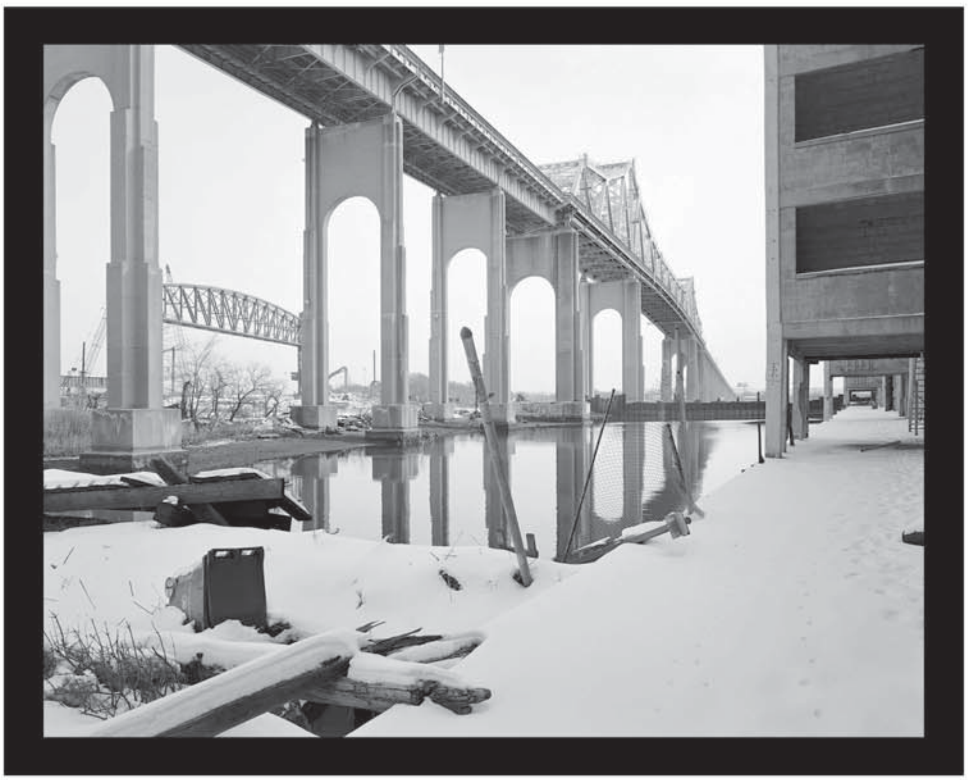

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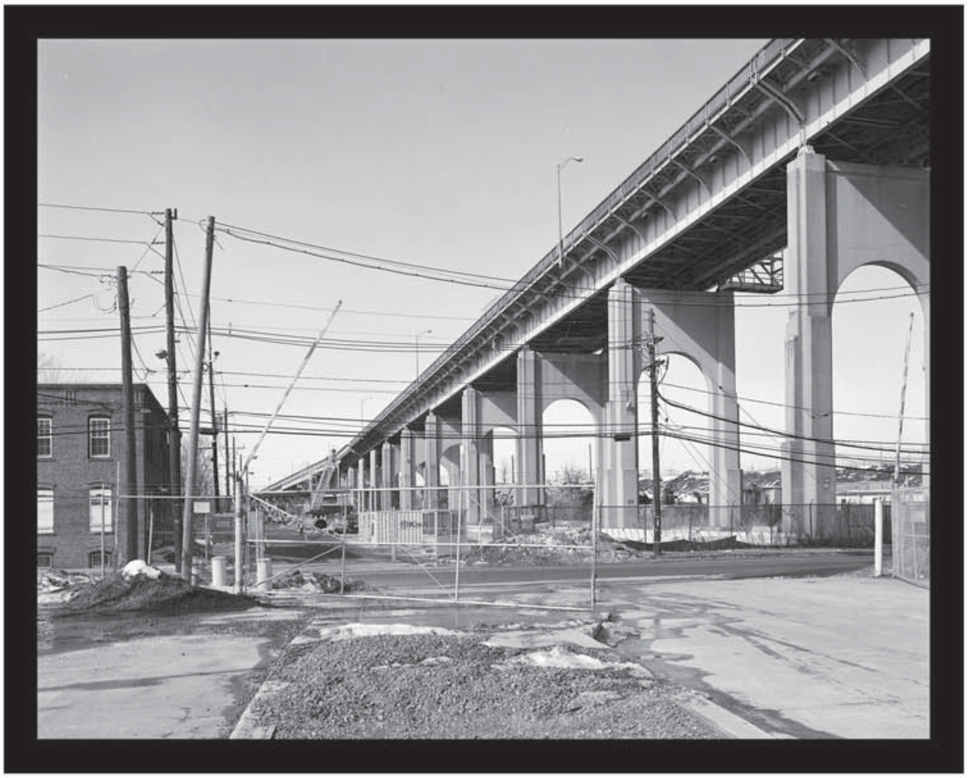

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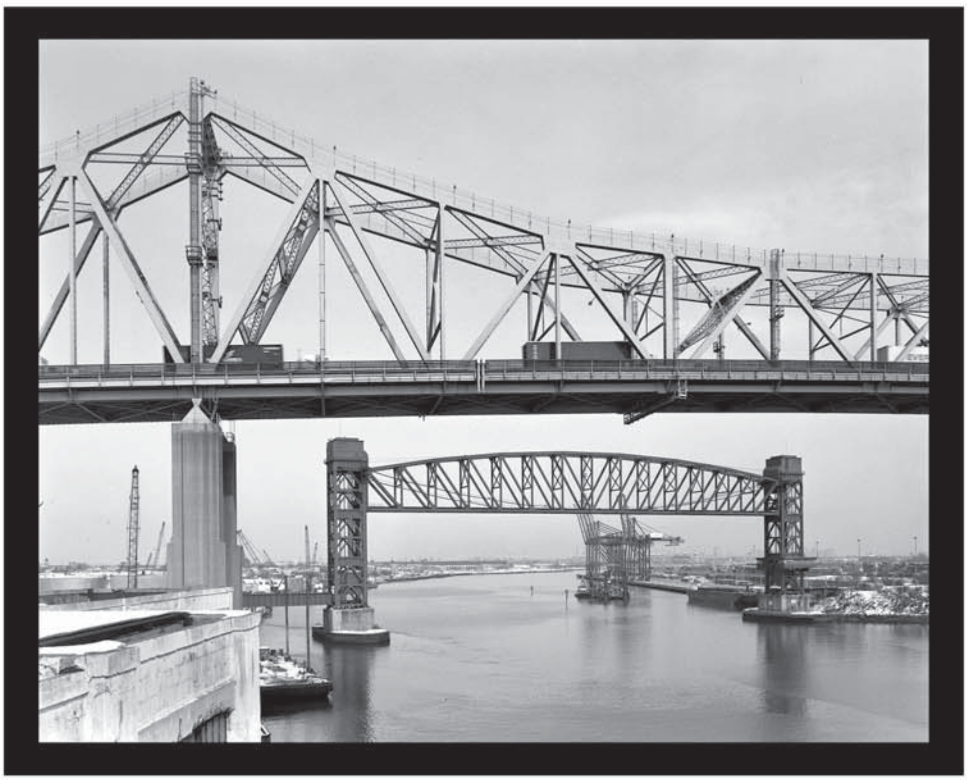

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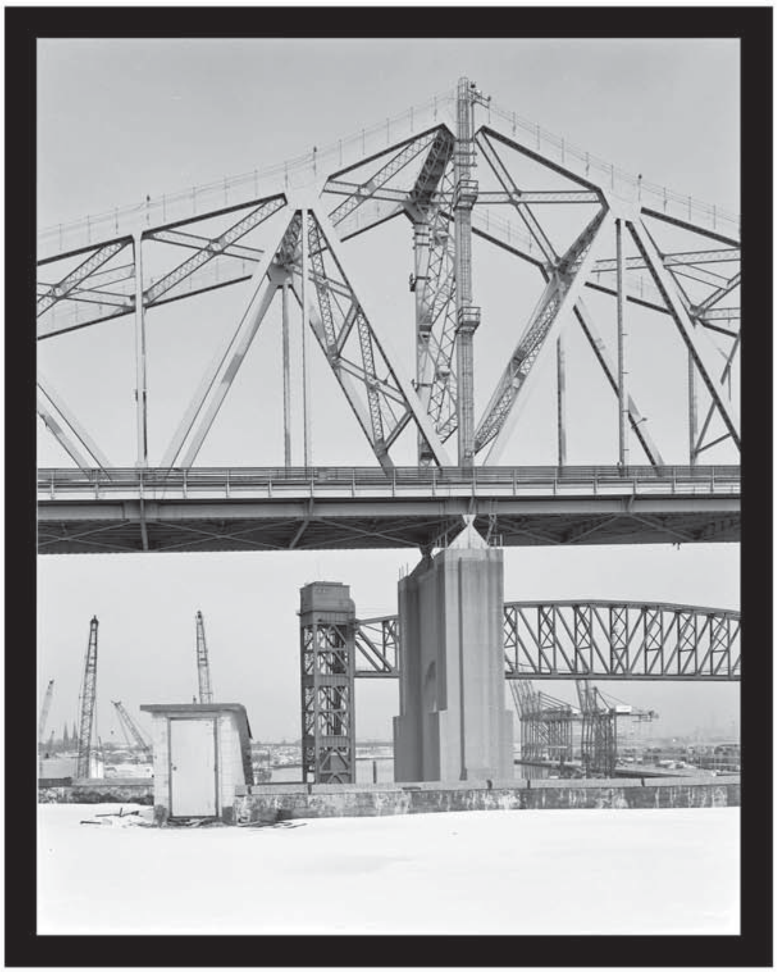

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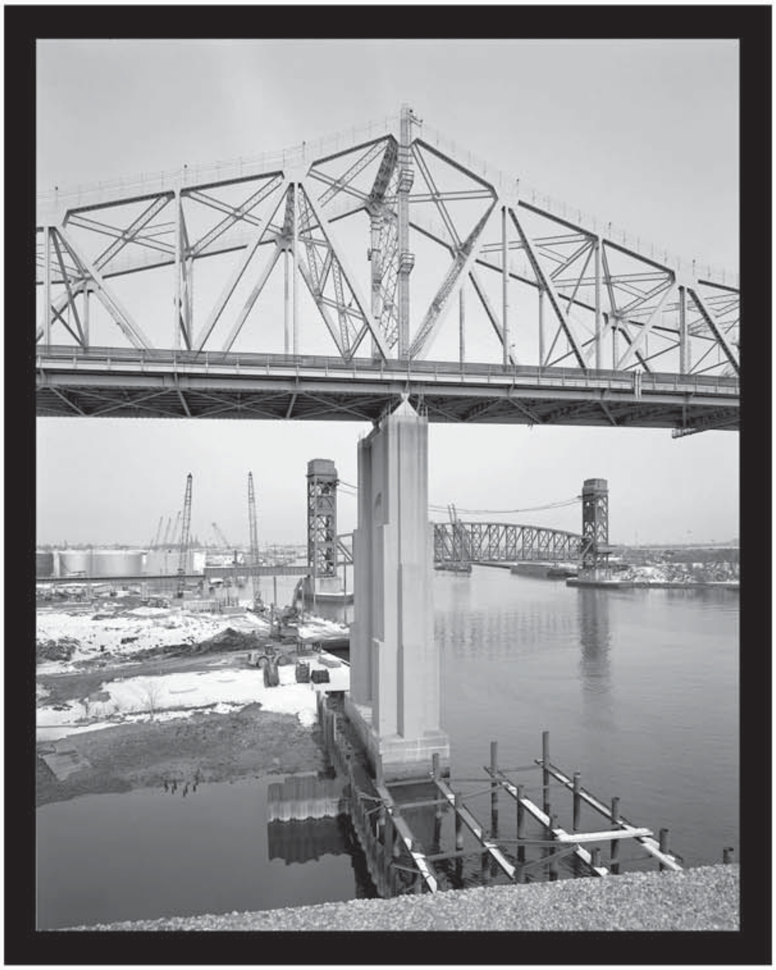

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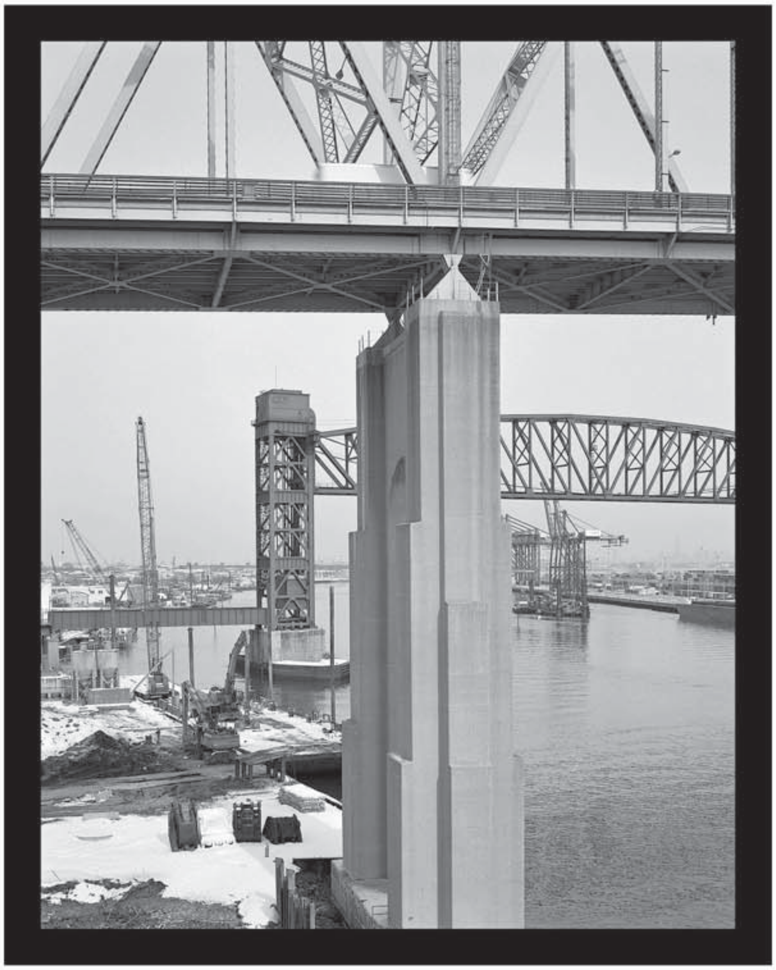

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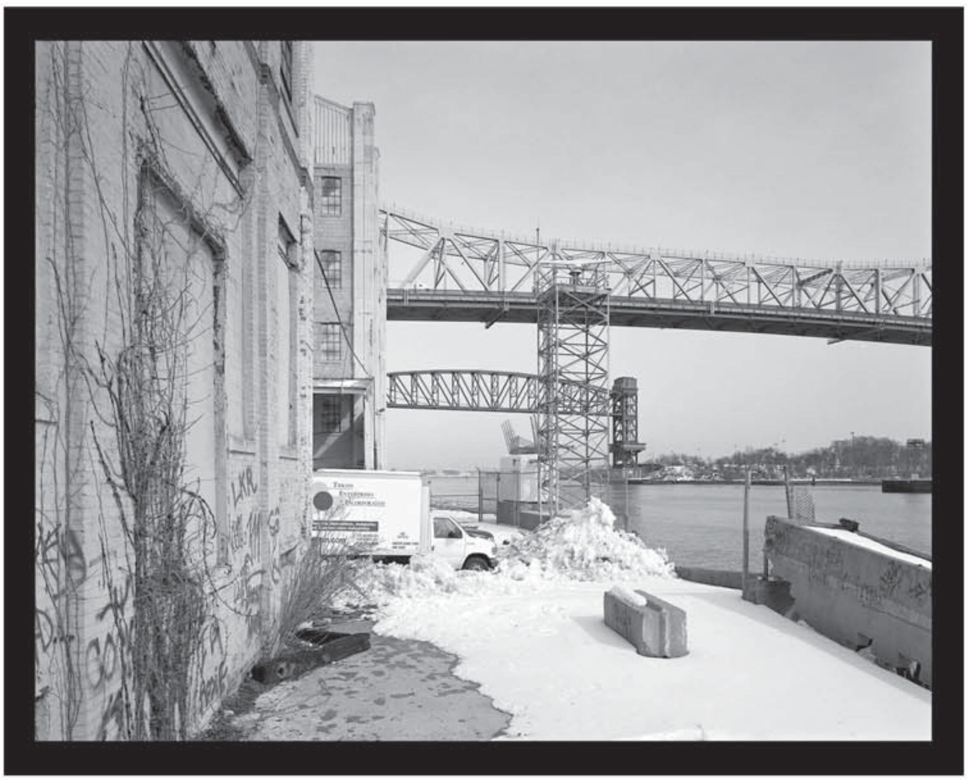

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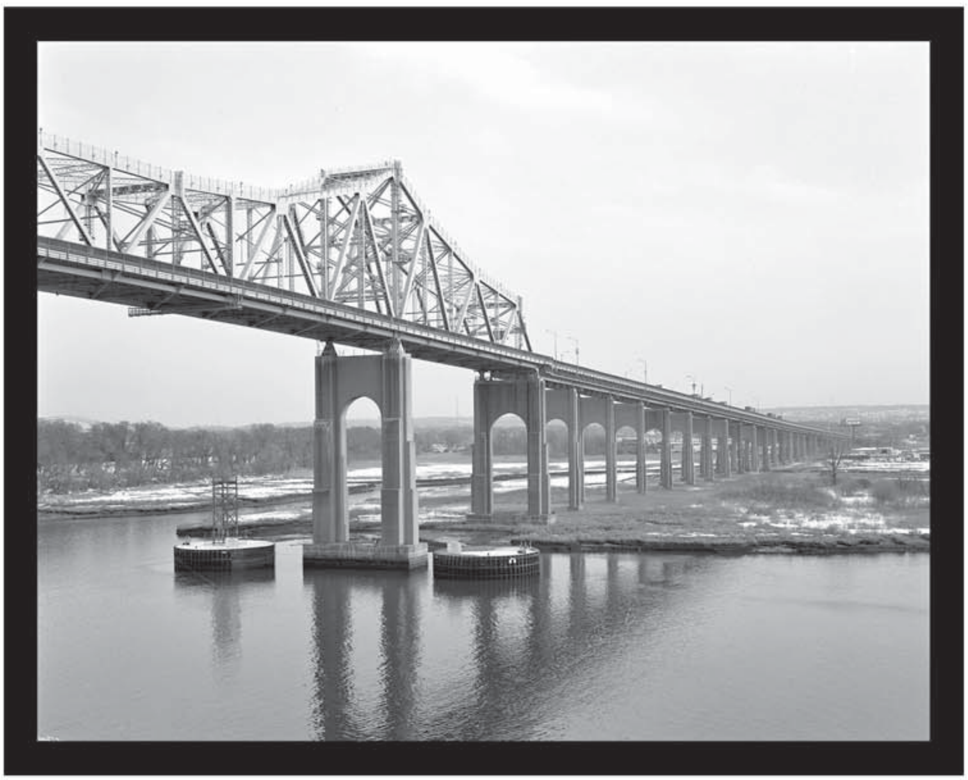

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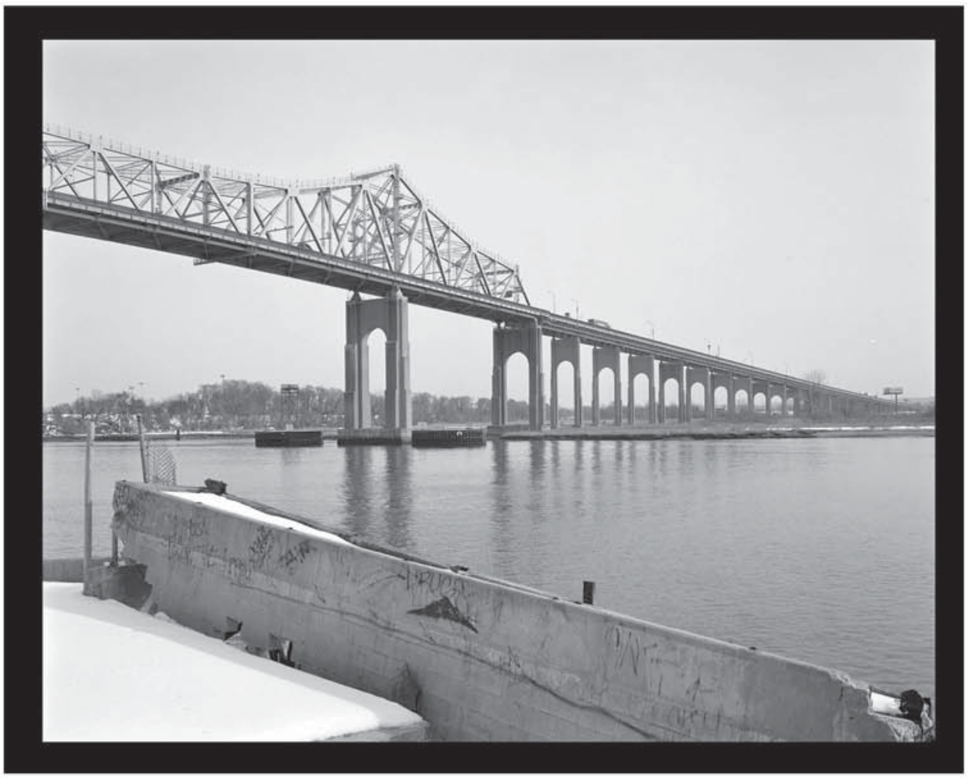

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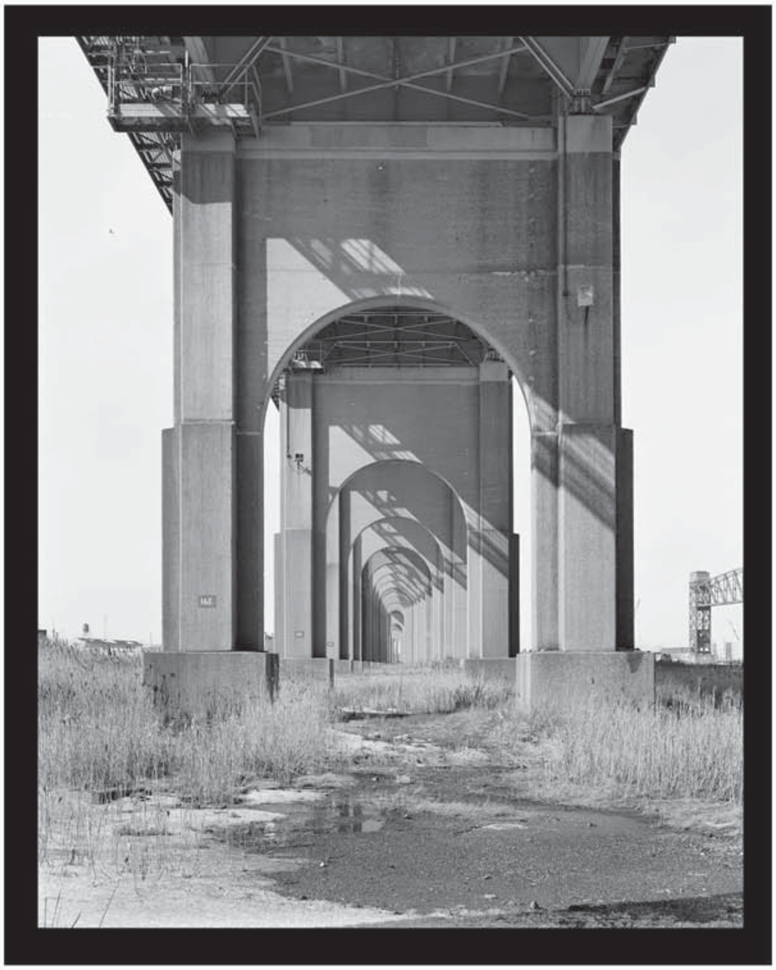

HISTORIC AMERICAN ENGINEERING RECORD

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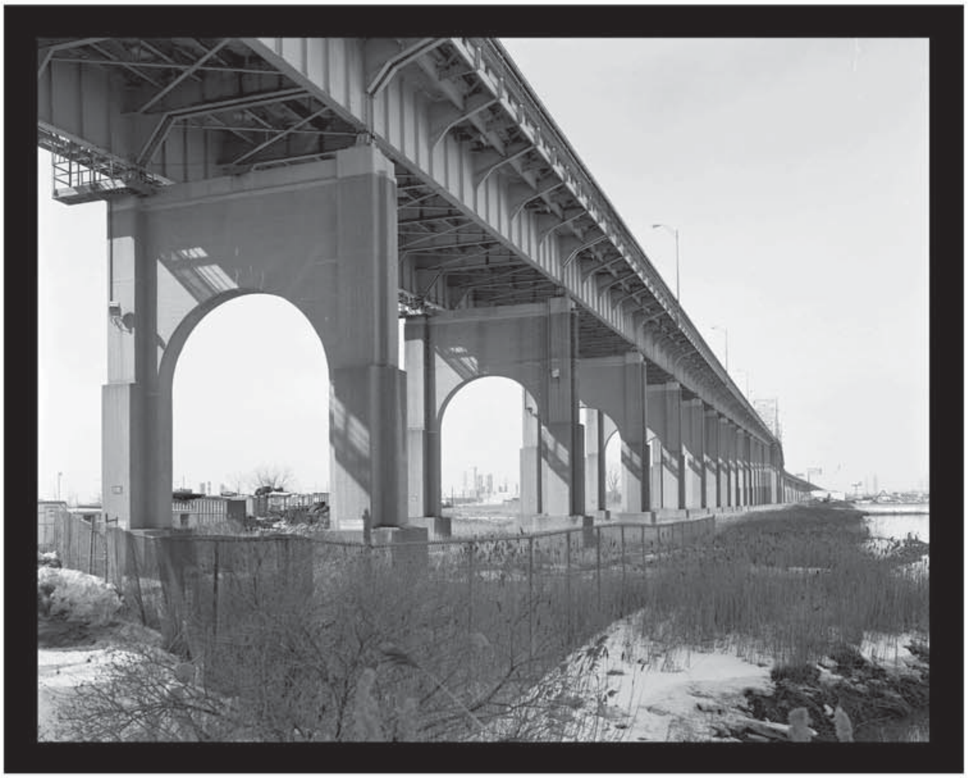

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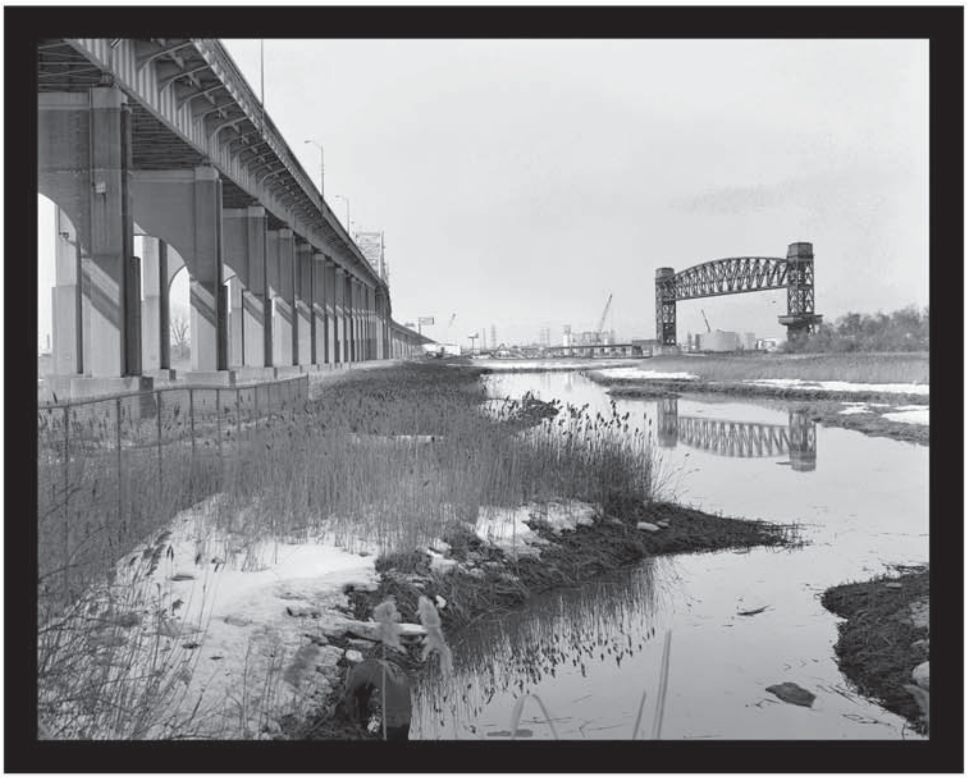

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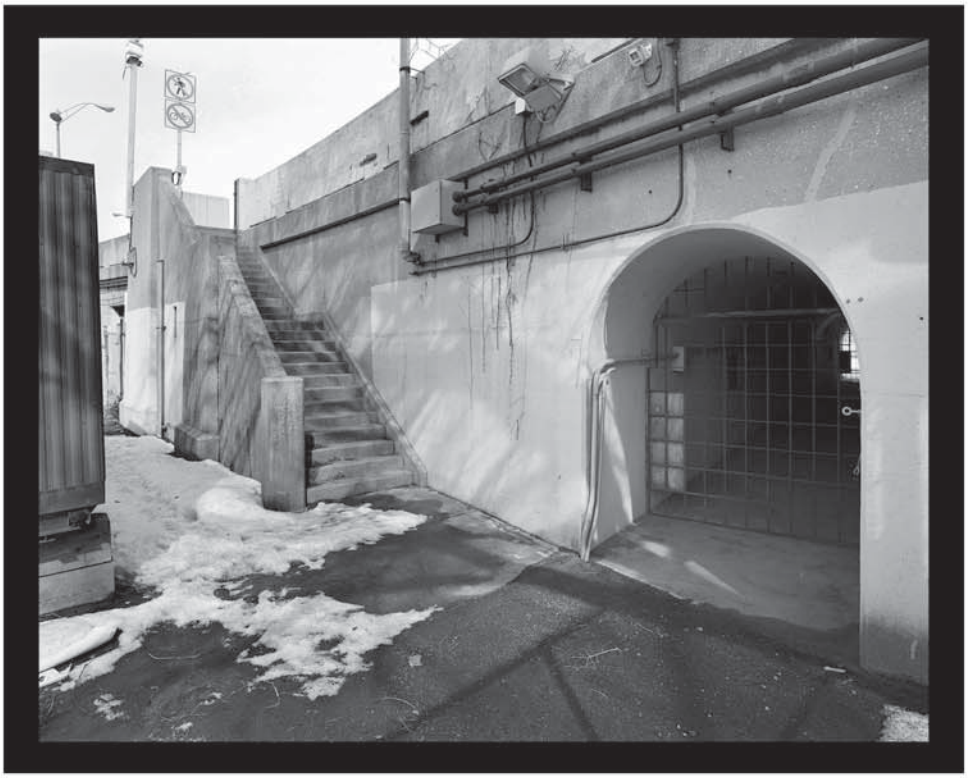

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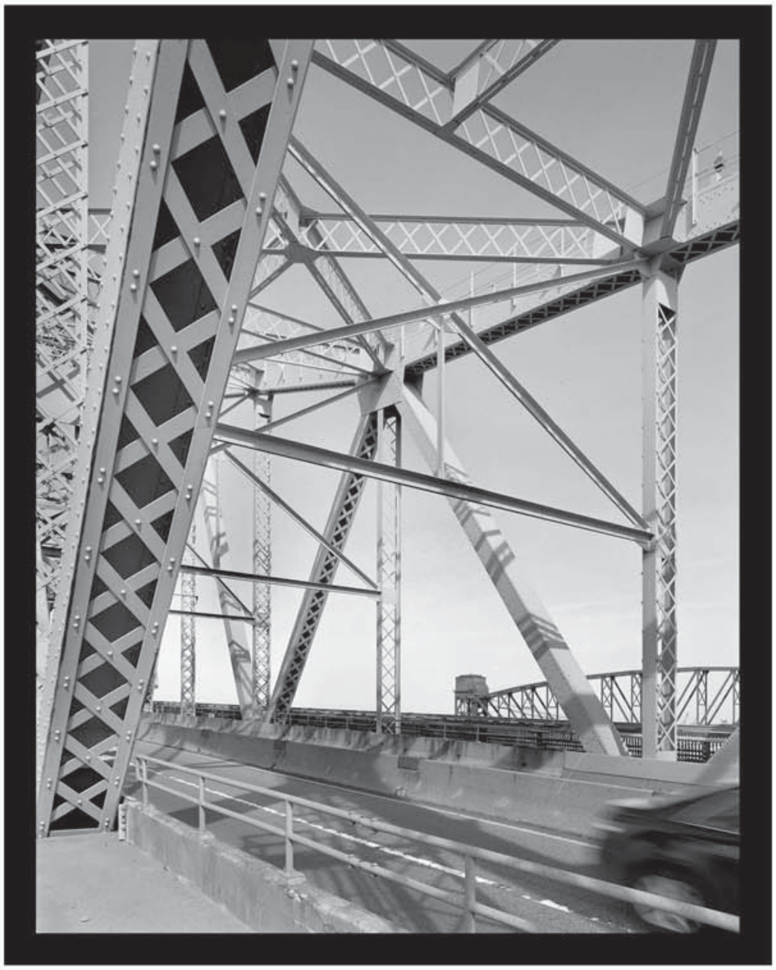

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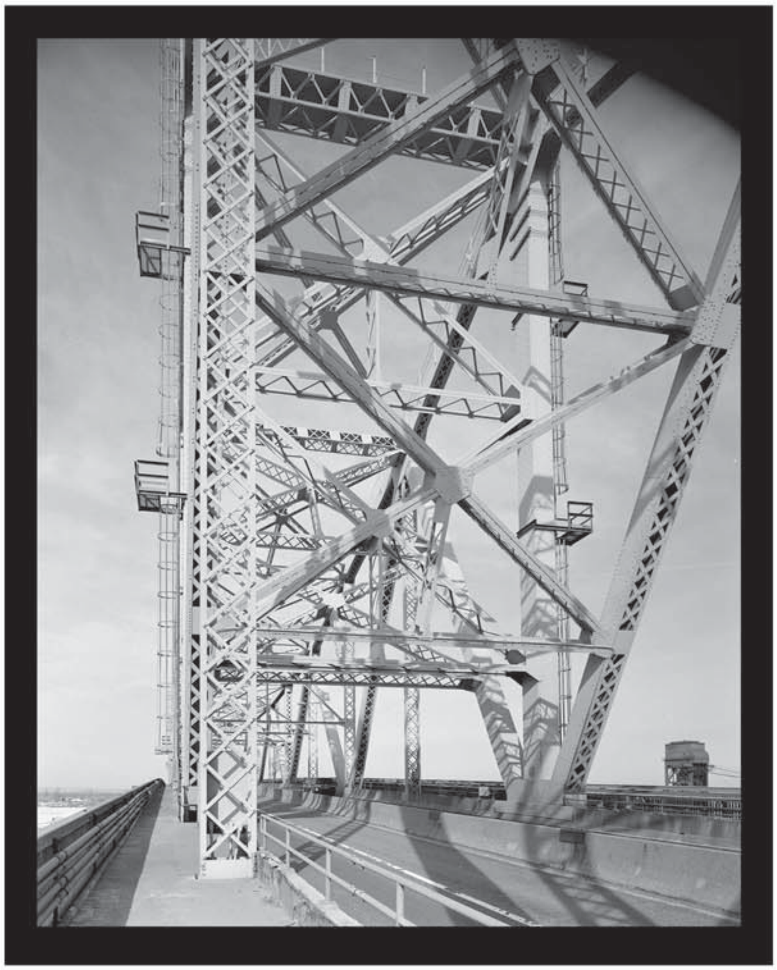

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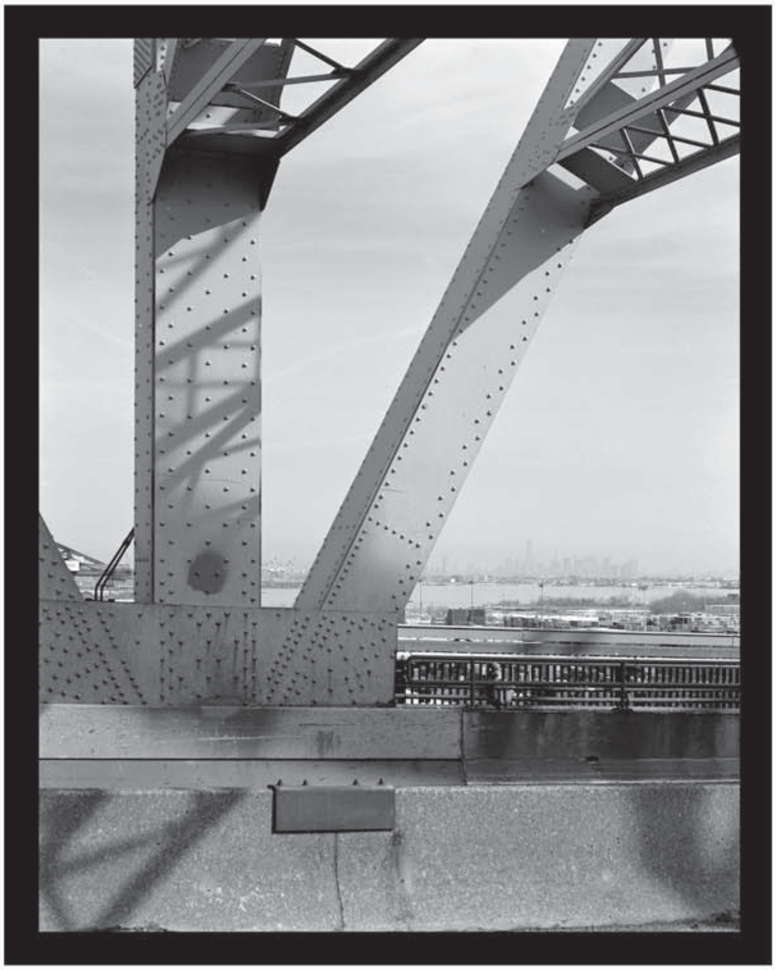

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