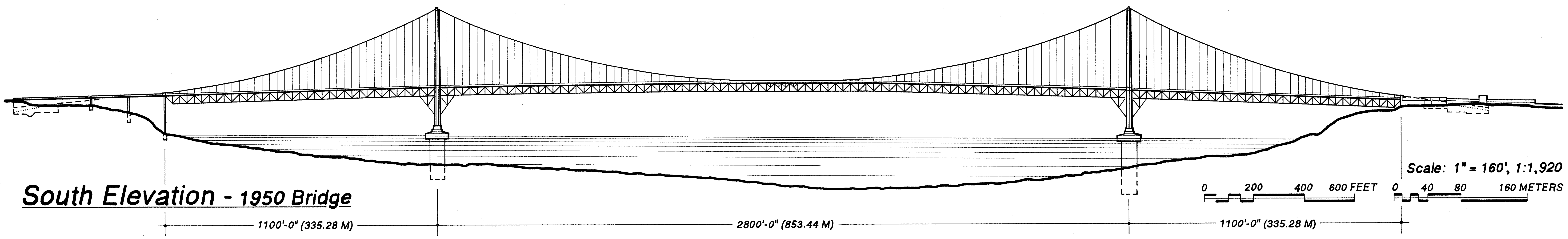
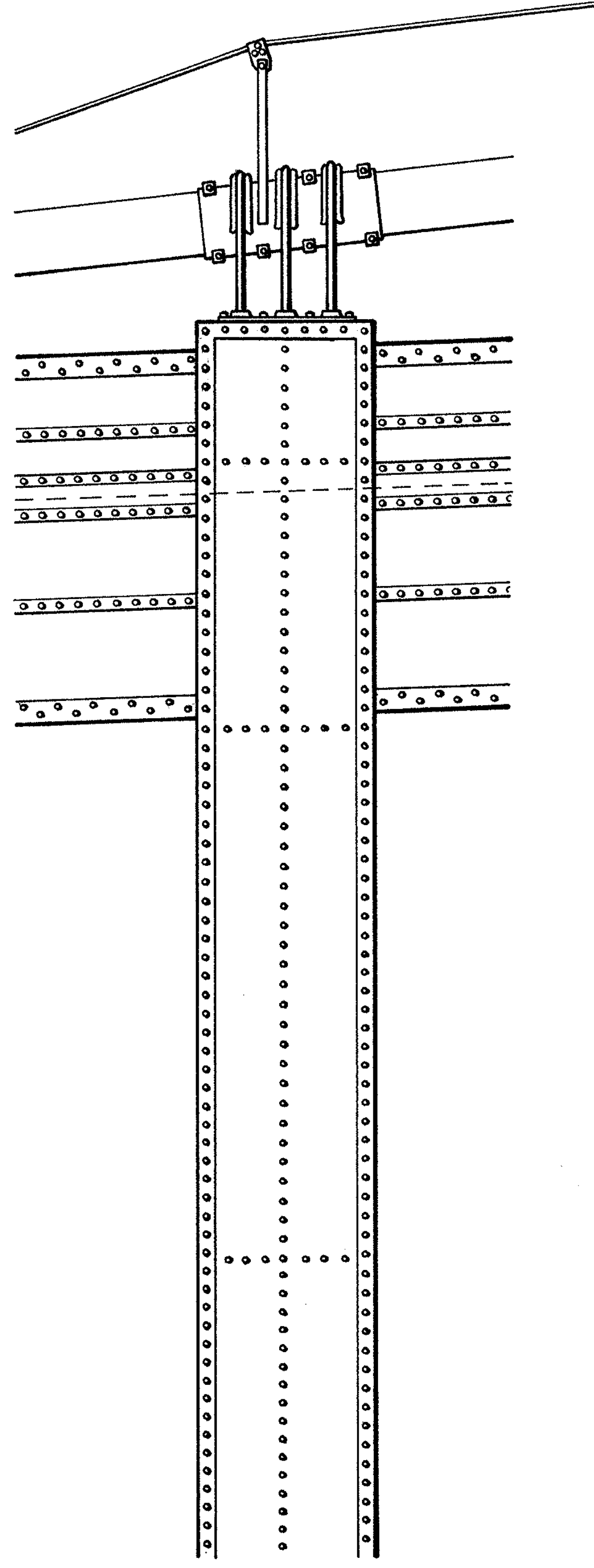


South Elevation - 1950 Bridge

TACOMA NARROWS BRIDGE

1940 · TACOMA, WASHINGTON · 1950



Detail

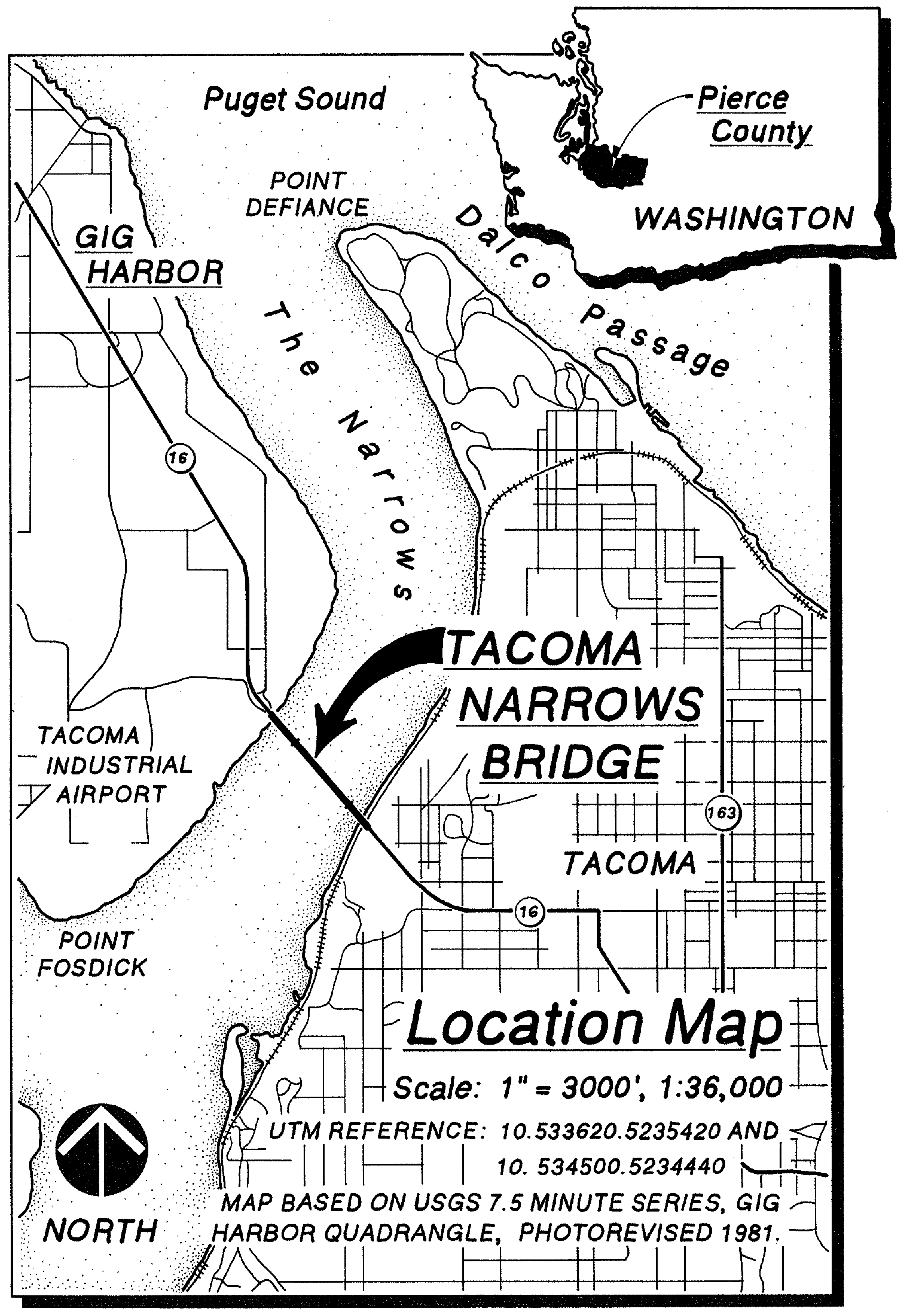
Hold Down Ropes at Tower No. 3 - 1940 Bridge

Scale: 3/8" = 1'-0", 1:32

The Washington Toll Bridge Authority built the 5,000-foot, $14 million Tacoma Narrows Bridge in 1950 to replace a previous structure, designed by the respected engineer Leon S. Moisseiff, that collapsed in 1940 from aerodynamic instability. Like its predecessor, it was the world's third longest suspension bridge, behind only the Golden Gate and the George Washington bridge for length of suspended span. But unlike its predecessor, the second Tacoma Narrows Bridge was built with several features that made it unaffected by wind forces. It marked a new beginning for the structural engineering field in this type of construction. Bethlehem Pacific Coast Steel Corporation was the general contractor. John A. Roebling's Sons Co. supplied the cable work.

University of Washington structural engineers directed by F. B. Farquharson attempted to understand the first structure's flaws through wind tunnel testing of dynamic scale models. They pioneered the field of bridge aerodynamics with the fruits of their research resulting in the design of the second Tacoma Narrows Bridge and other bridges that followed.

Charles E. Andrew and Dexter R. Smith, principal design engineers, incorporated many elements in the new bridge directed at preventing the dangerous twisting and galloping motions that destroyed its predecessor. These included deep open deck trusses, rather than shallow plate girders, that insured greater structural rigidity and, when combined with deck grating between traffic lanes, less wind resistance. A larger roadway width-to-span length increased twisting resistance and reliable damping mechanisms prevented the indefinite progressive increase in aerodynamic oscillation magnitude seen in the earlier bridge.



Location Map

Scale: 1" = 3000', 1:36,000

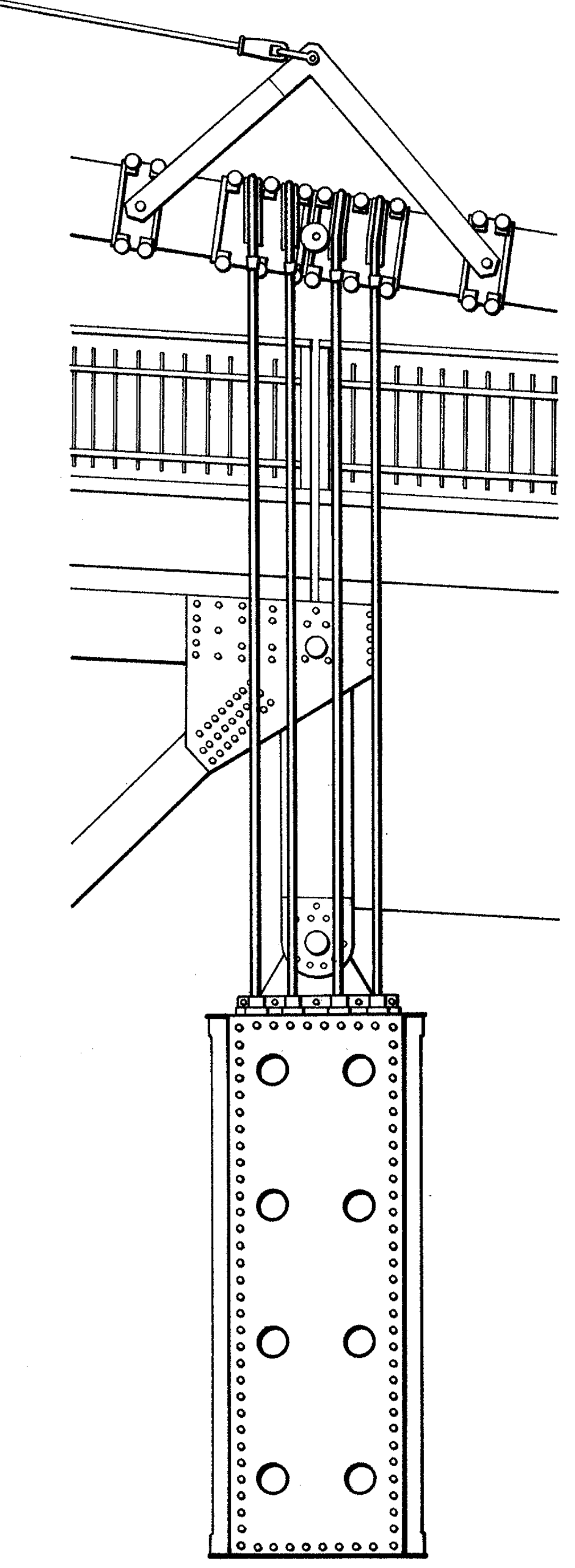
UTM REFERENCE: 10.533620.5235420 AND 10. 534500.5234440

MAP BASED ON USGS 7.5 MINUTE SERIES, GIG HARBOR QUADRANGLE, PHOTOREVISED 1981.

This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. The HAER program is administered by the Historic American Buildings Survey/Historic American Engineering Record Division (HABS/HAER) of the National Park Service, U.S. Department of the Interior. The Washington State Bridges Recording Project was cosponsored during the summer of 1993 by HABS/HAER under the general direction of Dr. Robert J. Kapsch, Chief, and by the Washington State Department of Transportation (WSDOT), Bernie L. Chaplin, Environmental Program Manager.

The field work, measured drawings, historical reports, and photographs were prepared under the direction of Project Leader Eric N. DeLony, Chief of HAER and HAER Historian Dean A.Herrin,Ph.D. The recording team consisted of Supervisory Architect Karl W. Stumpf (University of Illinois at Urbana-Champaign); Supervisory Historian Robert W. Hadlow, Ph.D. (Washington State University); Architects Vivian Chi (University of Maryland), Erin M. Doherty (Miami University), Catherine I. Kudlik (The Catholic University of America) and Wolfgang G. Mayr (US/ICOMOS, Technical University of Vienna, Austria); Historians Jonathan C. Clarke (US/ICOMOS, Ironbridge Institute, England) and Wm. Michael Lawrence (University of Illinois at Urbana-Champaign). Formal photography was done by HAER Photographer Jet Lowe. WSDOT Cultural Resources Specialist Elizabeth A. Robbins served as department liaison.

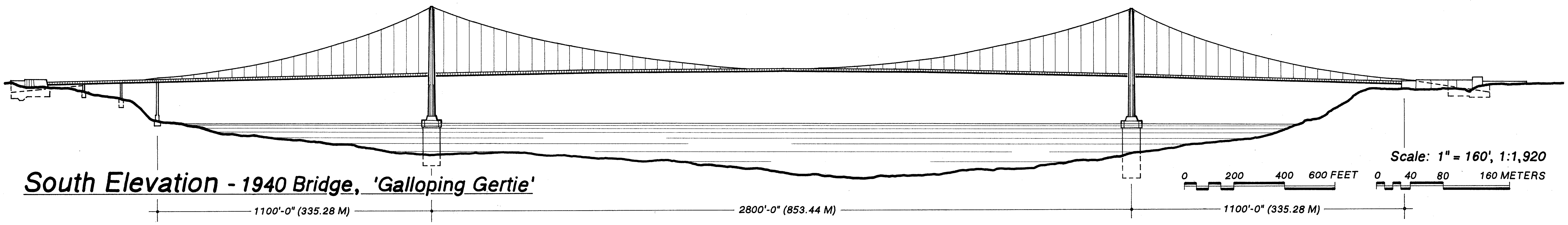
Drawings were developed from construction documents of the 1940 and 1950 bridges located in WSDOT files and field measurments.



Detail

Hold Down Cables at Tower No. 3 - 1950 Bridge

Scale: 3/8" = 1'-0", 1:32



South Elevation - 1940 Bridge, 'Galloping Gertie'

DRAWN BY: *Karl W. Stumpf and Wolfgang G. Mayr, Summer 1993*

WASHINGTON STATE BRIDGES RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

TACOMA

TACOMA NARROWS BRIDGE - 1950
STATE ROUTE 16 SPANNING THE NARROWS
PIERCE COUNTY

WASHINGTON

SHEET 1 OF 2 SHEETS

HISTORIC AMERICAN ENGINEERING RECORD
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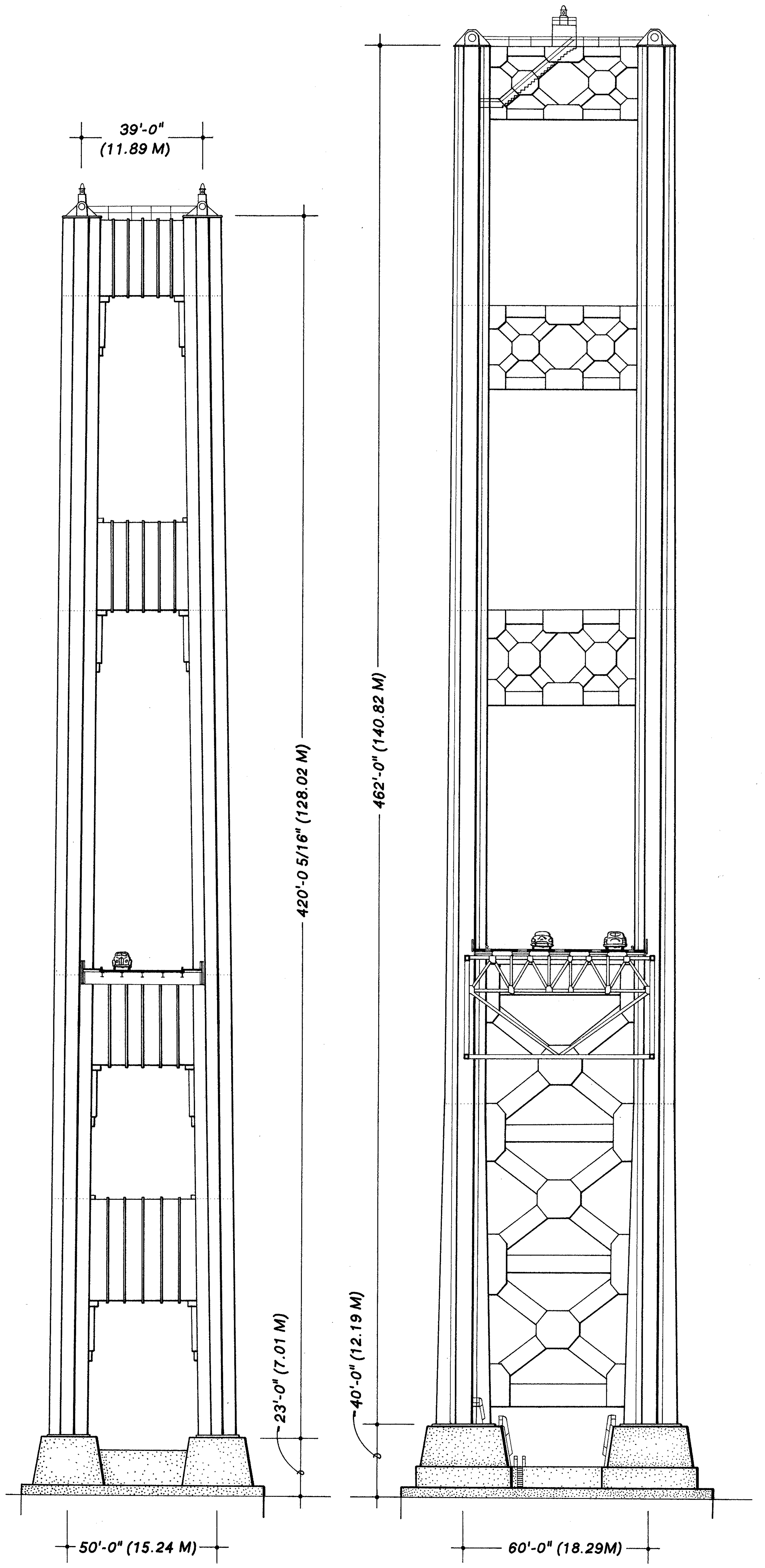
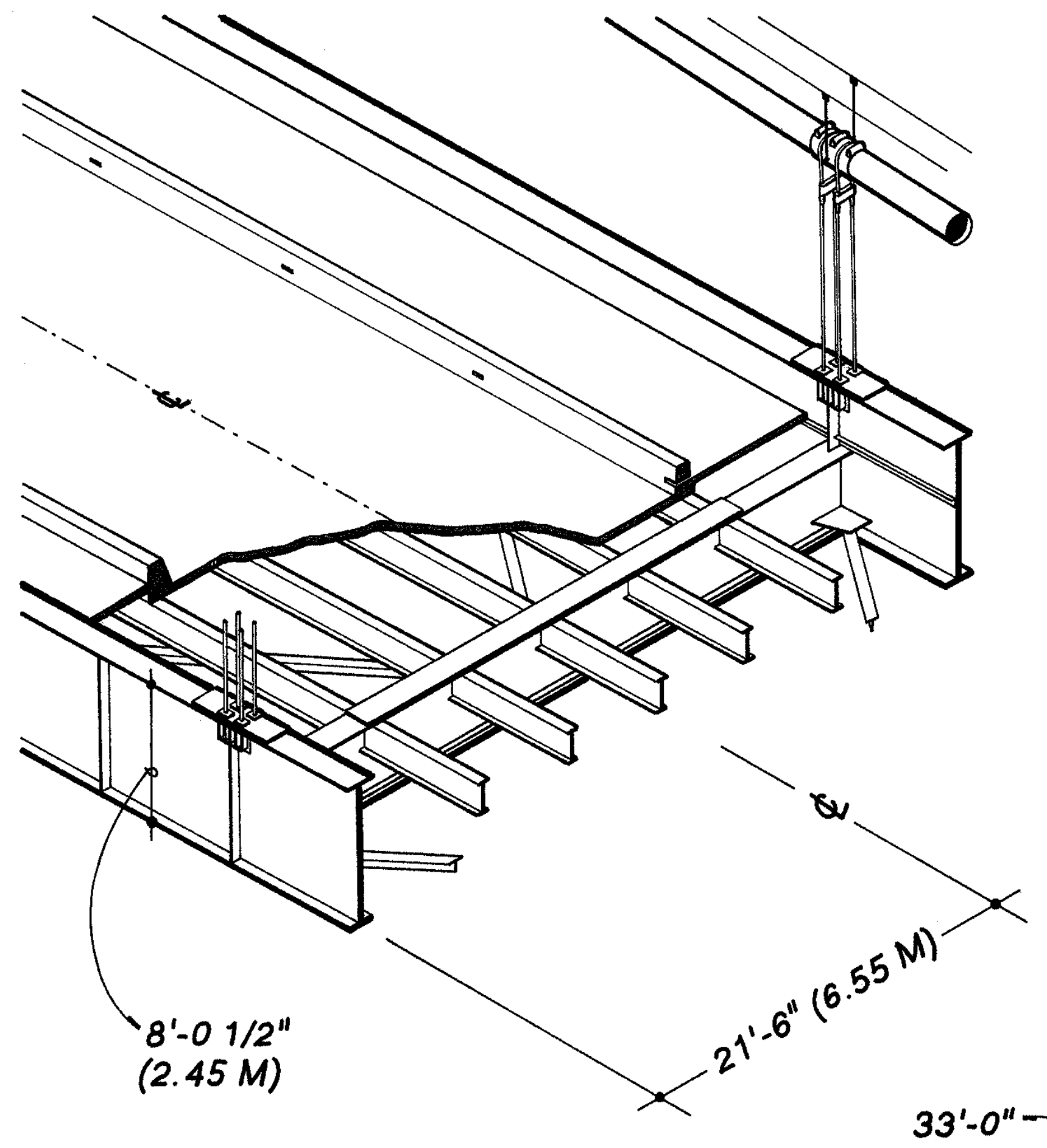


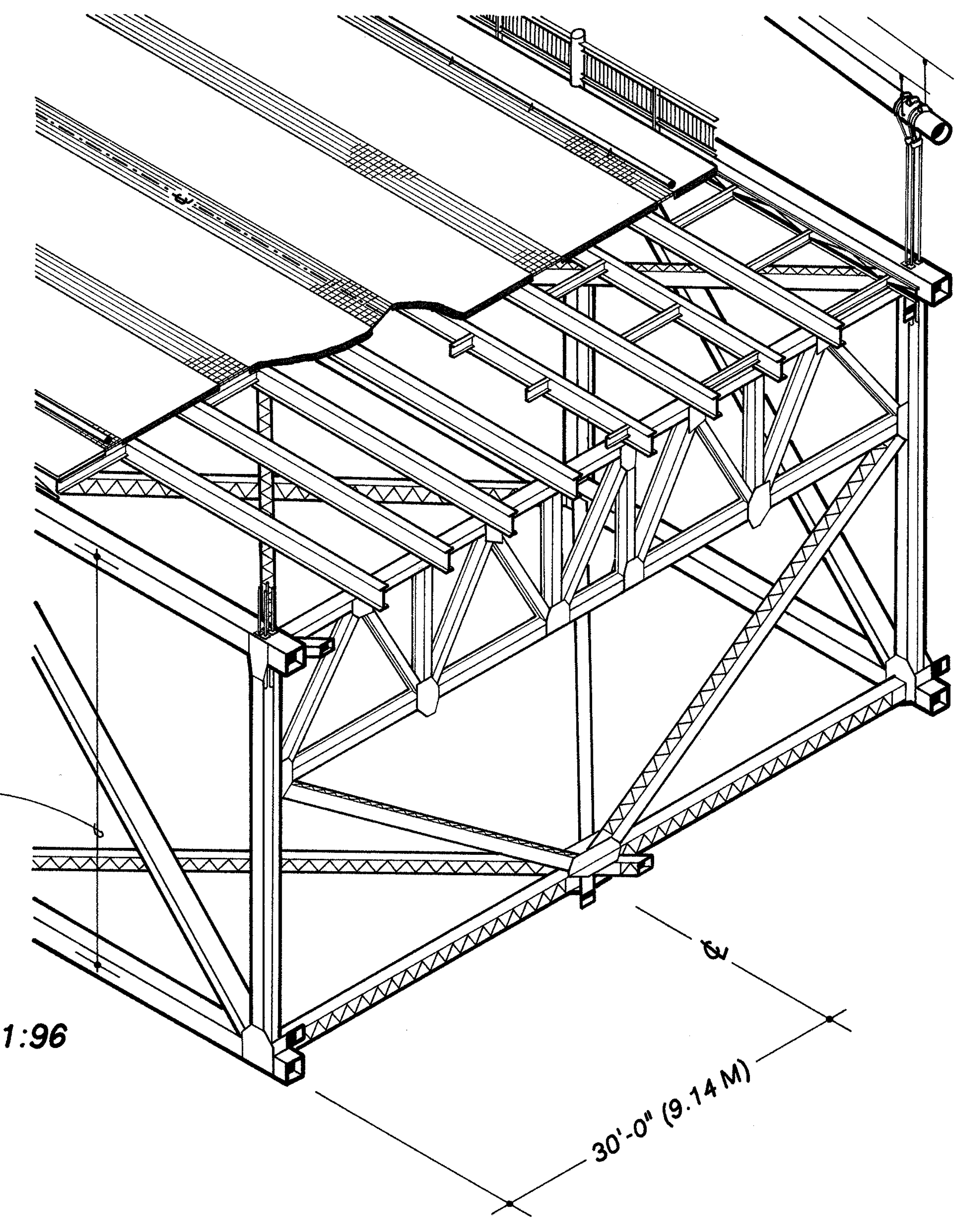
1940 Bridge Scale: 1" = 20', 1:240 **1950 Bridge**

The towers of the 1940 bridge accomodated a two-lane road deck. Tower legs for the 1950 bridge were designed for a four-lane road deck. Wider pier pedestals were erected for the new tower legs. They were also lengthened 18 feet to raise the tower steel above the Narrows' corrosive salt water.

Tower Elevations



1940 Bridge Roadway



1950 Bridge Roadway

Axonometrics

Scale: 1/8" = 1'-0", 1:96

The Tacoma Narrows Bridge collapsed on 7 November 1940 during a gale between 35 to 42 miles per hour, with a wind pressure of only five pounds per square foot. The steady wind's effects on the structure produced a fluctuating resultant force that synchronized in timing and direction with the bridge's natural harmonic motions (figs. 1&2), progressively amplifying them to destructive levels. Both vertical and torsional oscillations contributed to the failure of the bridge. The bridge's inherent weakness and susceptibility to these winds lay in its shallow stiffening girders and its narrow roadway.

Theodore von Karman, who had pioneered wind tunnel analysis at the California Institute of Technology, argued that the bridge deck's aerodynamic shape was a more important factor in its failure than its lightness and flexibility. Von Karman suspected that the bridge had experienced vortex shedding, a condition where objects like airplane wings or bridge decks displace air flowing around them and form eddies or vortices, which may induce vibration in the object (figs 3&4). He believed that wind flowing over the bridge's solid girder side plates created shedding that when combined with the flutter and resonance already present in the deck produced the violent oscillations that caused the catastrophic failure (figs. 5&6).

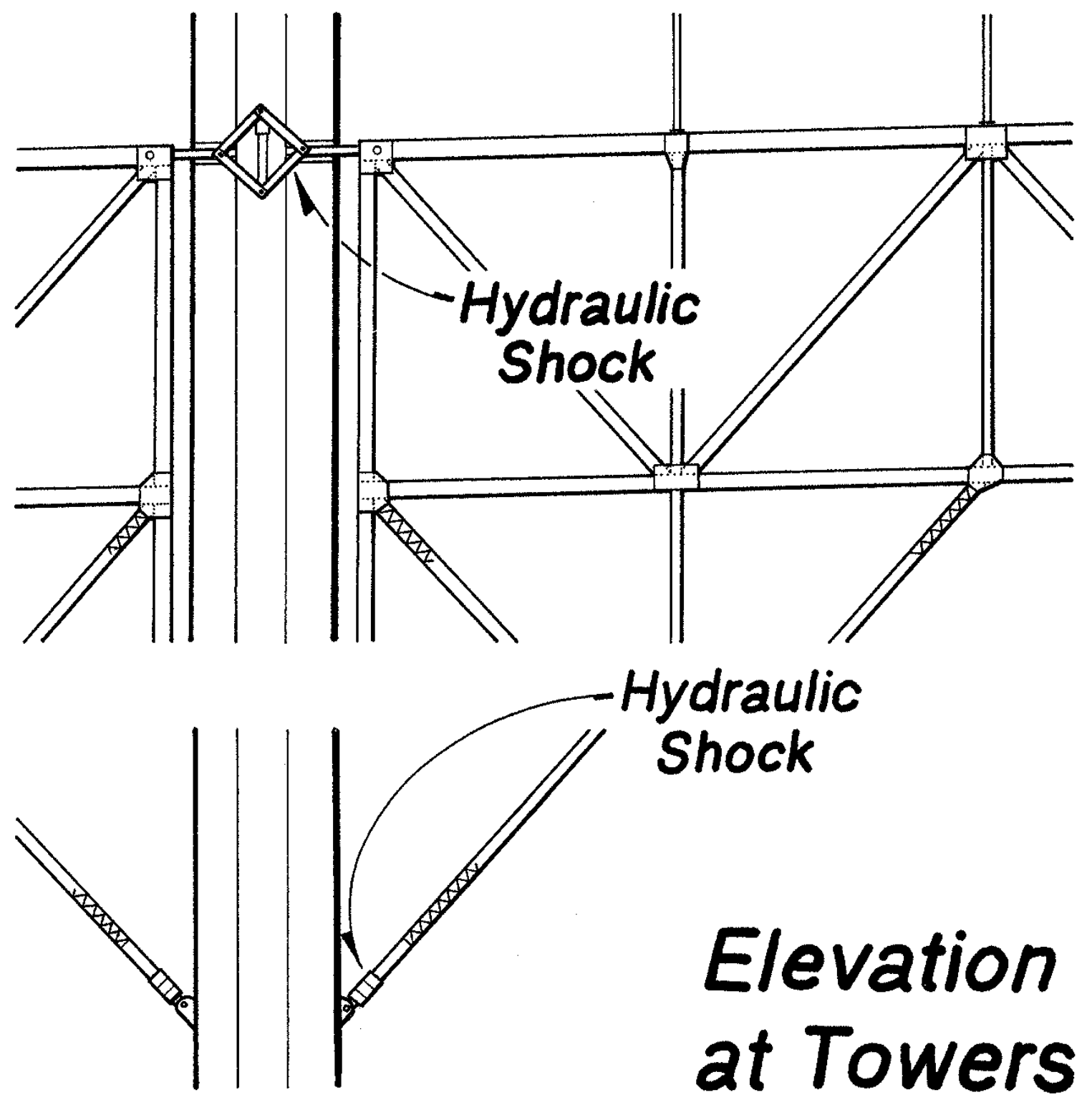
Designing the replacement bridge's deck stiffening system involved subjecting dynamic scale models to wind tunnel testing to better understand wind effects on them.

Designers for the 1950 bridge were not satisfied with their ability to eliminate torsional and vertical movements in their proposed structure. They hoped to enhance their design's natural damping ability with mechanical devices. One of these was a double-lateral bracing system in the stiffening truss. It increased torsional frequency motion and tortional stiffness.

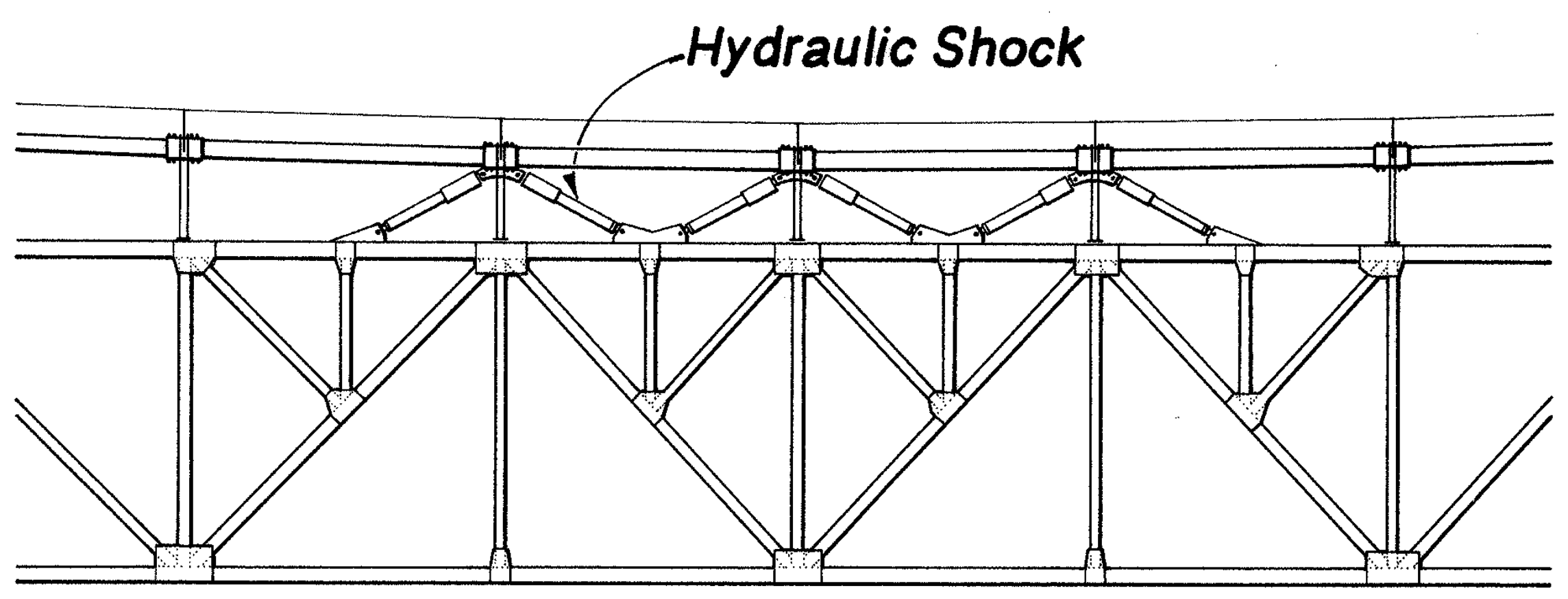
Damping Mechanism

1950 Bridge

Scale: 1/16" = 1'-0", 1:192



Elevation at Towers



Elevation at Mid-Span

To eliminate torsional and vertical movement cylindrical hydraulic shock absorbers were used at three points on the bridge: coupling the top of the stiffening truss at mid-span with the suspension cables, connecting between the top chords of the main span and side span stiffening trusses, and extending as outriggers from the trusses' bottom chords to the towers.

1940 Bridge Failure

Diagrams & Illustrations

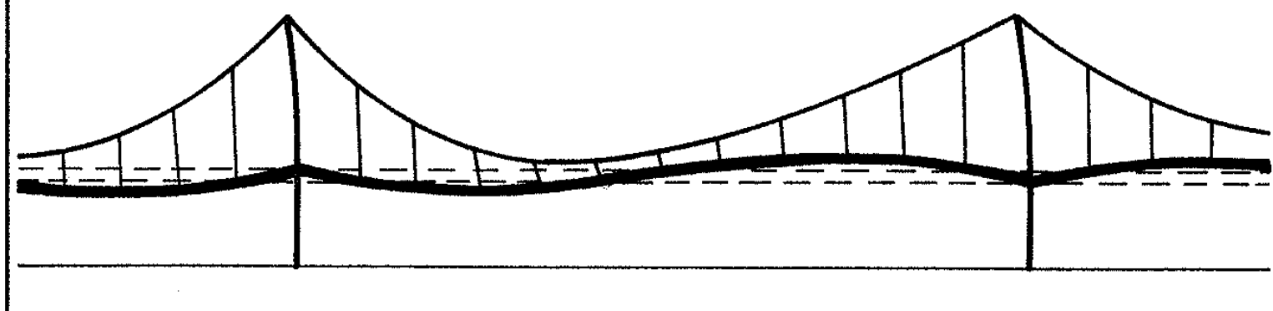


FIGURE 1

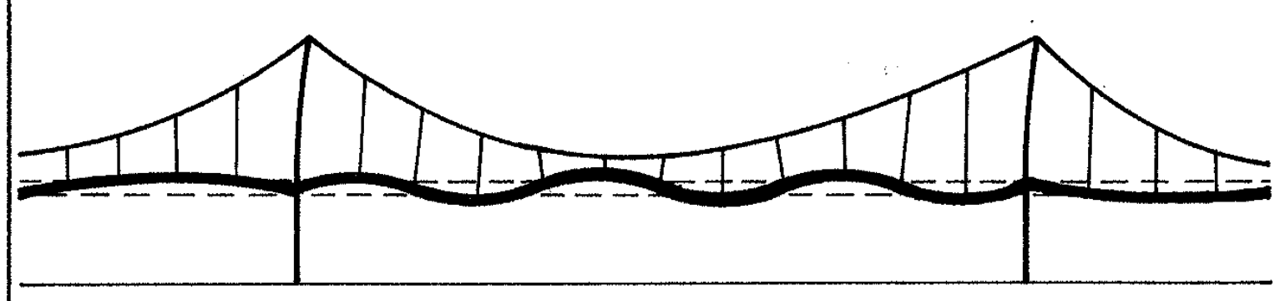


FIGURE 2

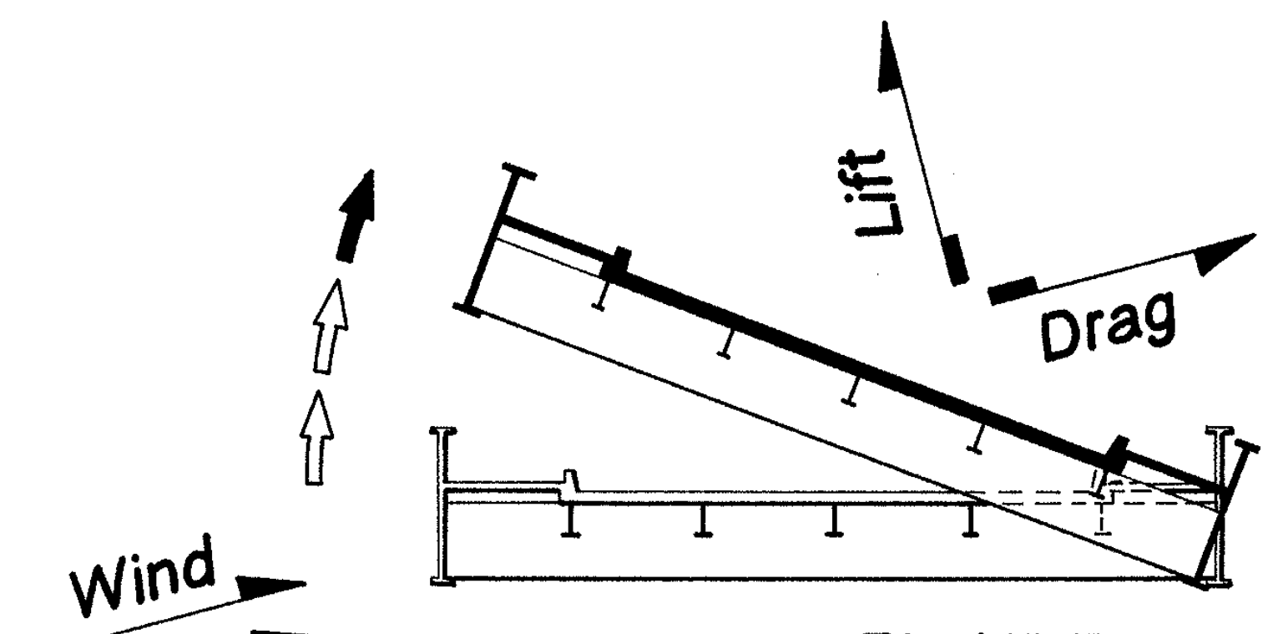


FIGURE 3

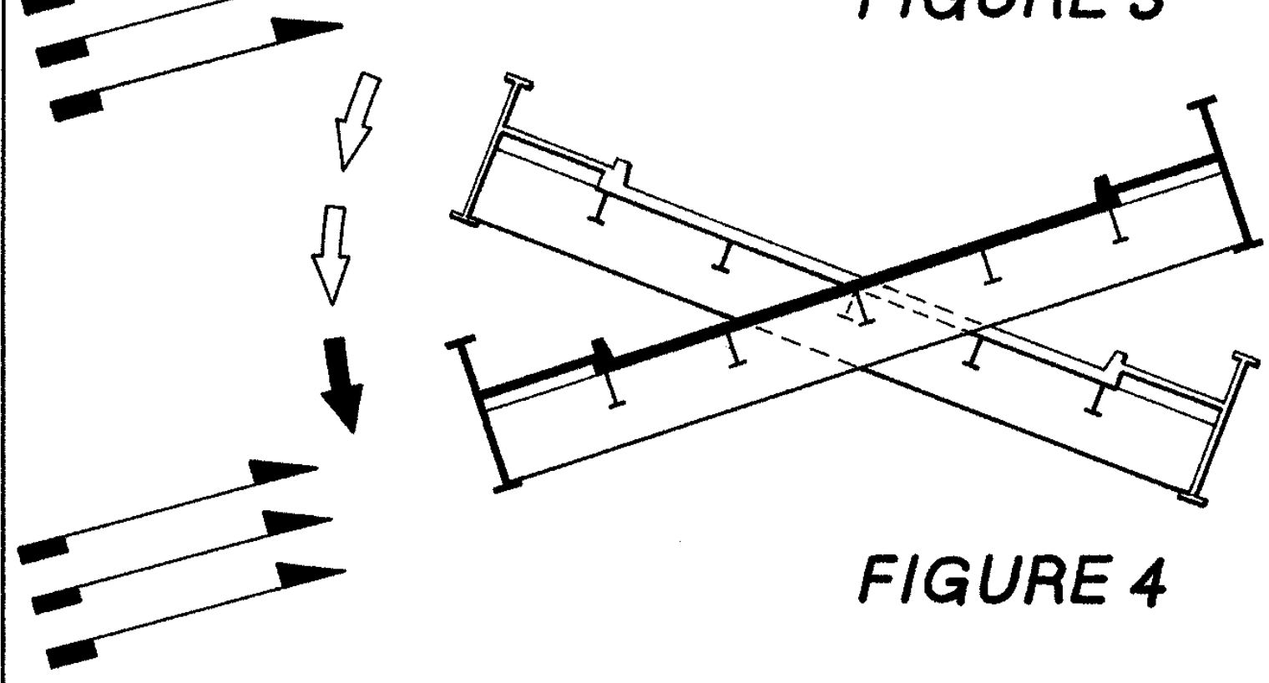


FIGURE 4

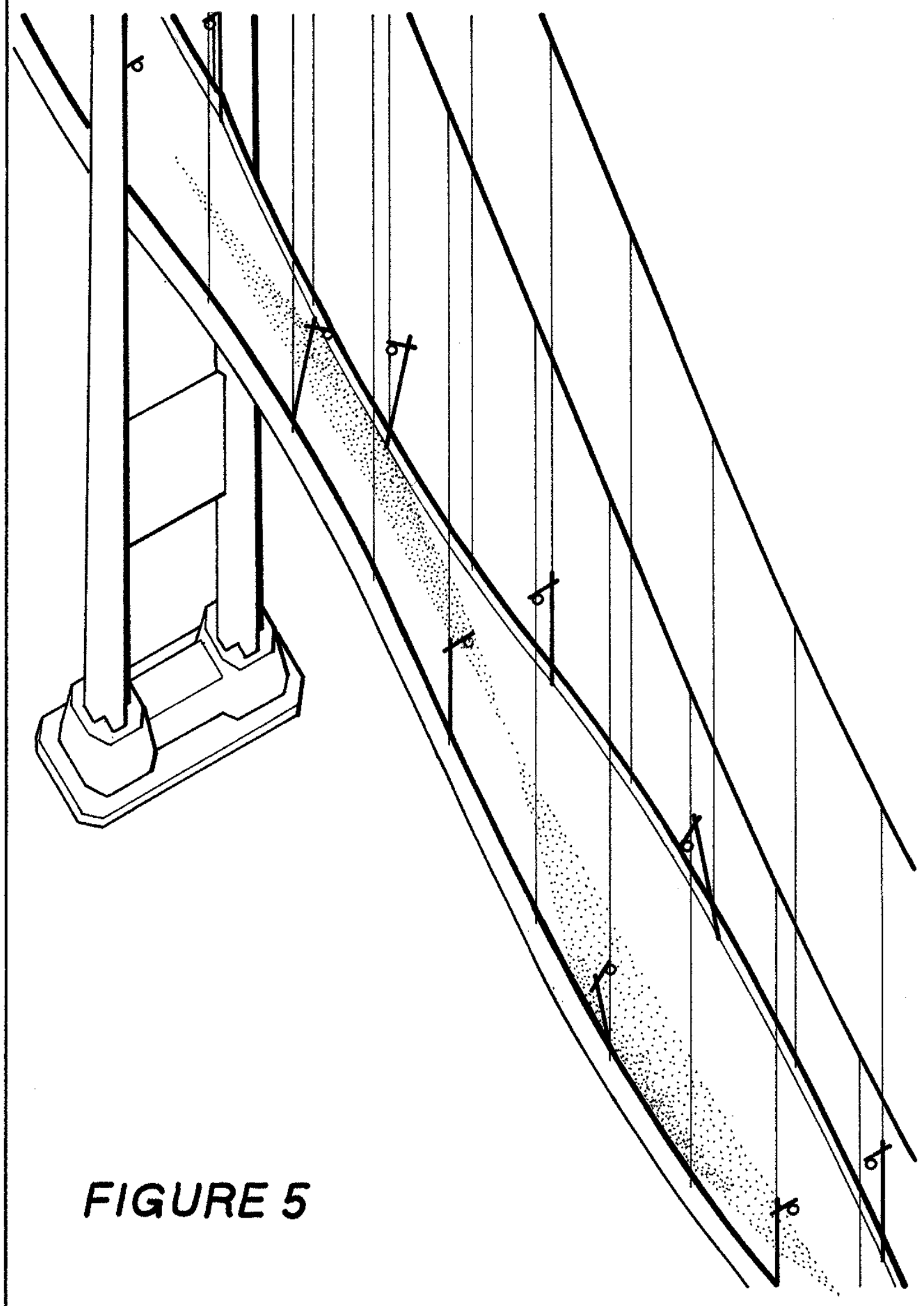


FIGURE 5

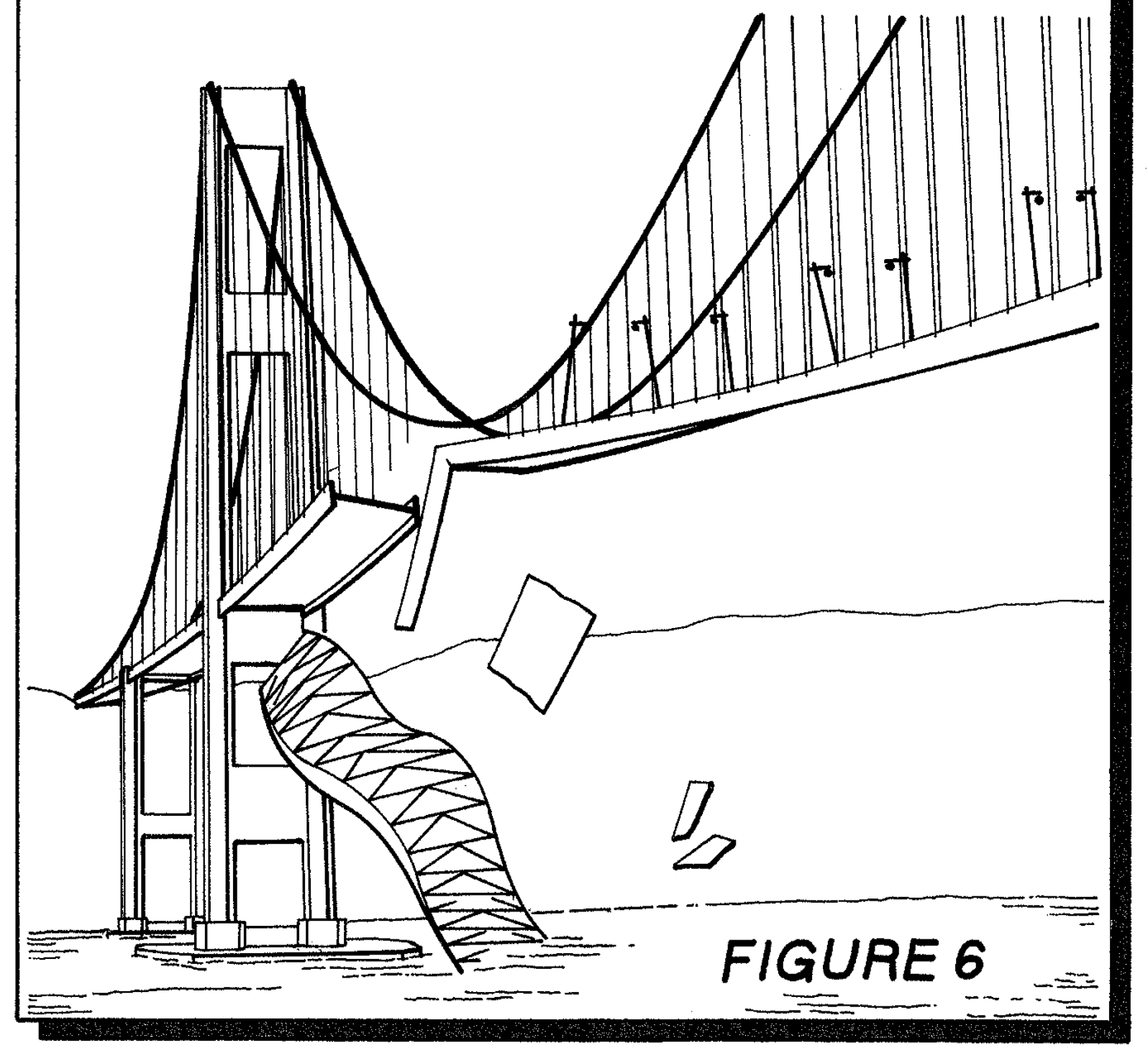


FIGURE 6

TACOMA NARROWS BRIDGE - 1950
STATE ROUTE 16 SPANNING THE NARROWS
PIERCE COUNTY

TACOMA

WASHINGTON

DRAWN BY: Wolfgang G. Mayr, Summer 1993

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