Broadway Bridge Project

Movable Span Bridge Type Selection Report

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Executive Summary

This Bridge Type Selection Report details the process followed by Modjeski and Masters (M&M), for the Mark Thomas project team, and the Cities of West Sacramento and Sacramento in selecting and further developing movable bridge alternatives for the proposed Broadway Bridge. The following were the primary goals of this study:

- Provide analysis and a construction cost estimate for each viable movable span alternative
- Recommend the movable bridge types that will be carried forward into the next phase of the project.

Several types of vertical lifts, two leaf bascules, and swing spans were evaluated for the new movable span. A summary of movable bridge alternatives that were considered for this study are as follows:

Bascule Bridges

Alternative A – Fully Counterweighted Two Leaf Deck Bascule Girder
Alternative B – Partially Counterweighted Two Leaf Deck Bascule Girder
Alternative C – Fully Counterweighted Two Leaf Rolling Bascule Truss
Alternative D – Partially Counterweighted Two Leaf Rolling Bascule Truss

Vertical Lift Bridges

Alternative E – Vertical Lift Girder Span with Concrete Frame Towers
Alternative F – Vertical Lift Girder Span with Steel Frame Towers
Alternative G – Vertical Lift Truss Span with Trussed Towers

Swing Bridges

Alternative H-1 – Bobtail Swing Through Truss Spans
Alternative H-2 – Swing Through Truss Spans
Alternative I-1 – Bobtail Swing Deck Girder Spans
Alternative I-2 – Swing Deck Girder Spans

The bridge alternatives were rated in an evaluation matrix using the following criteria:

- Performance
- Construction Costs
- Life Cycle Cost Considerations

The results of the evaluation indicate that the partially counterweighted two leaf rolling bascule, the vertical lift girder span with steel frame towers, and the vertical lift girder span with concrete towers are the preferred bridge types. The fully counterweighted bascule spans, the truss vertical lift, and the swing span alternatives did not score as highly and are recommended for further consideration.

It is recommended that the three preferred bridge types be continued into the next phase of design. Continuing with three distinct bridge types will allow the stakeholders, the public, and the bridge architect more options for developing a signature span. Also, the one structure type that will be advanced to final design may depend on additional project decisions such as determining the final alignment.

I. PROJECT OVERVIEW

A. Introduction

The purpose of this report is to assist the cities of West Sacramento and Sacramento in selecting one movable bridge alternative for the new Broadway Bridge. The following were the primary goals of this study:

- Provide analysis and a construction cost estimate for each viable alternative for the new Broadway Bridge
- Recommend the movable bridge type that will be carried forward into the next phase of the project.

The discussions included in this report are limited to the movable span of the new Broadway Bridge. Alignment studies and approach span alternatives are discussed in separate reports.

B. Project Description

The Broadway Bridge project includes the construction of a new structure connecting the Sacramento side of the Sacramento River near Broadway in the vicinity of Marina View Drive to the West Sacramento side near either 15th Street or South River Road. The purpose of the project is to create a low profile neighborhood friendly river crossing that will promote safety, mobility, accessibility, and support economic development throughout the project area. The new Broadway Bridge will be able to accommodate the future addition of a streetcar line.

C. Bridge Location and Alignments

The new Broadway Bridge will be located downstream of the U.S. Highway 50 Pioneer Memorial Bridge. At this stage of the project, four different alignments are being considered. Figure 1 shows the proposed bridge alignments. Alignments A and B require a navigation opening of 170 ft., Alignment C requires a navigation opening of 180 ft., and Alignment D requires a navigation opening of 240 ft. Conceptual level construction costs were developed for each alignment.

D. Profile

Two different roadway profiles were considered for the river crossing. The first consists of a lower profile where the top of the roadway is 9'-9" above the 200 year water surface elevation. This provides for a 6'-9" clearance between the profile grade and the low steel and 3'-0" clearance between low steel and design high water. The second profile is higher, where the top of the roadway is 17'-0" above the 200 year water surface elevation, which provides a 14'-0" clearance between the profile grade and the low steel and 3'-0" clearance. Both profiles provide for a similar overall structure length. The difference in the profile grade elevations at the movable span are achieved by changing the roadway grades for the approach spans. The higher profile allows for the consideration of deck type superstructure movable spans, but also have the advantage of using through type superstructure movable spans that provide a higher vertical clearance above water elevations. The higher clearance in the closed position has the advantage of possibly reducing the number of bridge openings which would help reduce the maintenance costs of the movable spans and inconvenience to traffic. The lower profile would allow for only the use of through type superstructure movable spans.

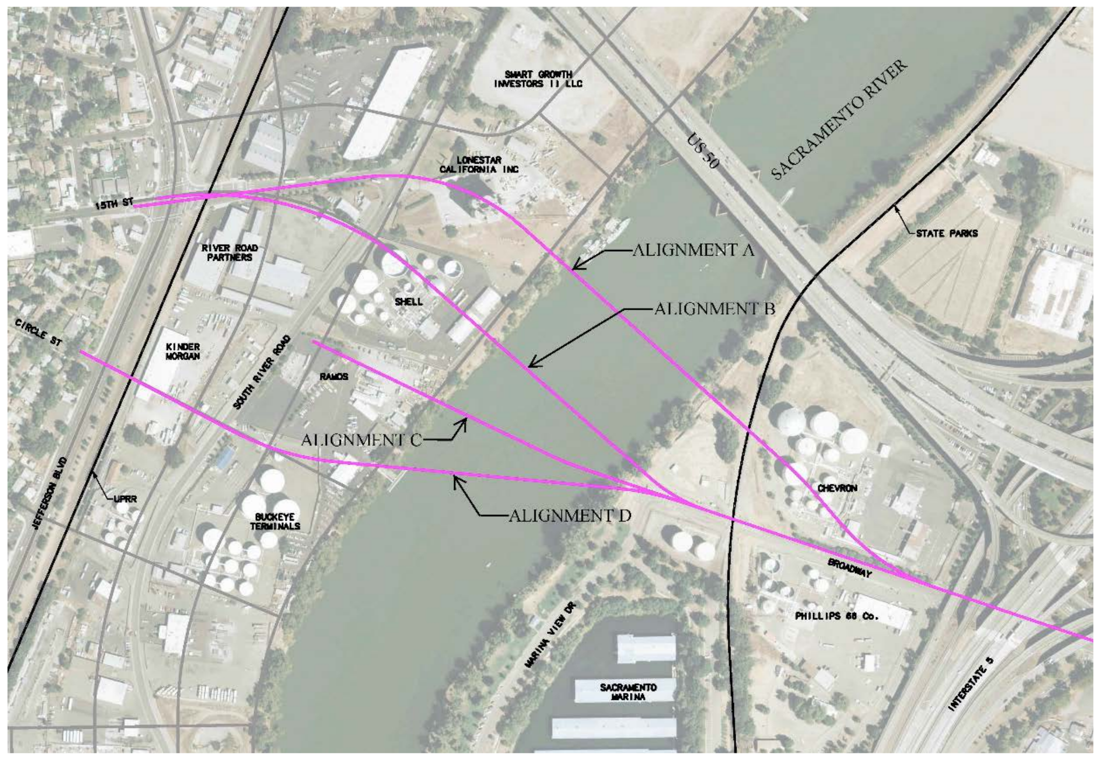


Figure 1 – Bridge Location Map

II. Design Considerations

The following criteria were used during the development of the new bridge alternatives. These criteria will be refined as the project develops to address specific areas where additional studies or investigations are required. Various assumptions were made for advancement of this study, and they are identified below.

Design Specifications

- *AASHTO LRFD Bridge Design Specifications, 6th Edition* with California Amendments (AASHTO LRFD)
- *AASHTO LRFD Movable Highway Bridge Design Specifications, 2nd Edition, with Interims up to 2015*
- *AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition, with Interims up to 2015*
- *AASHTO Guide Specifications for Vessel Collision Design of Highway Bridges*, 2010
- *California Department of Transportation (Caltrans) Bridge Design Specifications and Manuals*

System of Units

- All project documents shall be completed in Customary US Units

Bridge Cross Section

Representative bridge cross sections are shown in Figure 2 and Figure 3 with the following attributes. Figure 2 shows a typical through structure cross section and Figure 3 shows a typical deck structure cross section.

- 3 traffic lanes
- Lane width: 12'-0"
- Proposed shoulder width: 3'-0" between traffic lane and bike lane
- Median: none
- 2 Bike Lanes, each with a width of 6'-0"
- 2 Pedestrian Walkways, each with a width of 12'-0"
- Total out-to-out bridge width varies depending on superstructure type

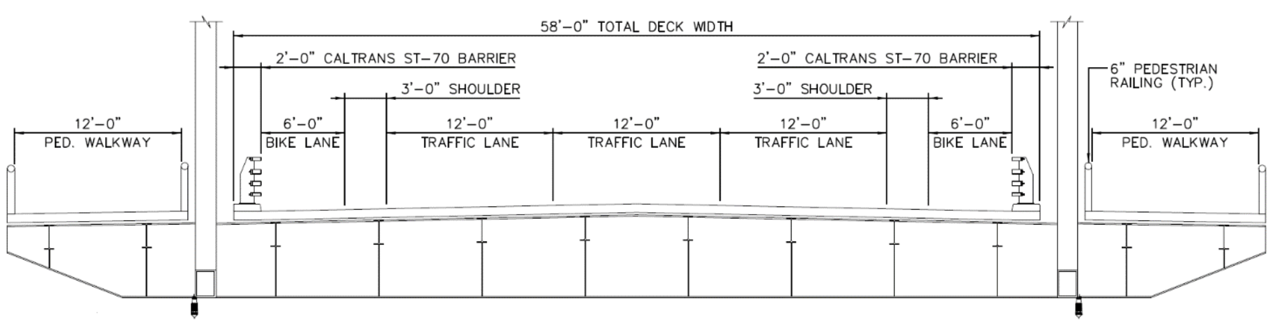


Figure 2 – Typical Through Structure Cross Section

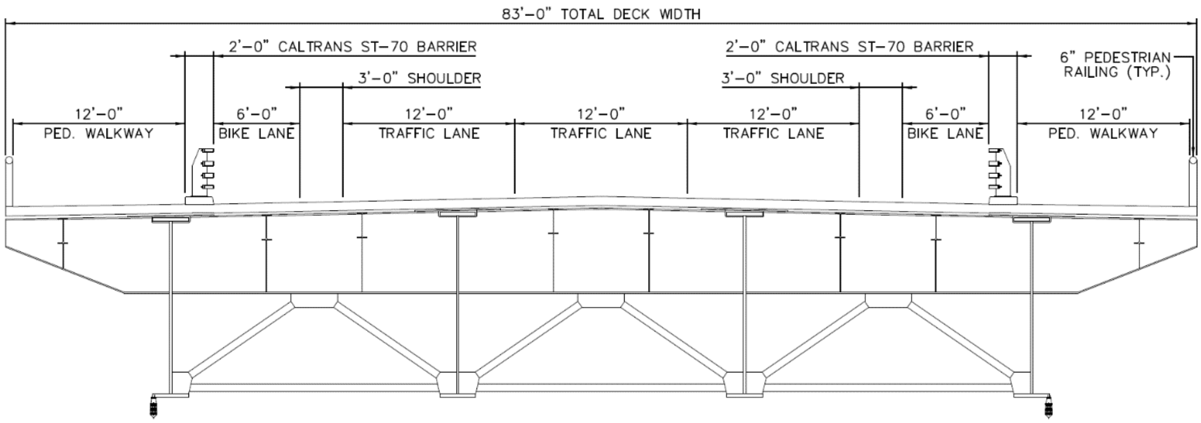


Figure 3 – Typical Deck Structure Cross Section

Roadway Geometry

Vertical Grade on the bridge shall maintain a low profile and meet the requirements for ADA access. The maximum vertical grade on the movable span is 1.5%.

There is no horizontal curve, within the limits of the movable span, on the proposed bridge alternatives.

Bridge cross slopes are as follows:

- Traffic lanes and bike lanes: 2%
- Pedestrian walkways: 1.5%

Required Navigational Clearances and Water Elevation

The design high water elevation is as follows. Elevations refer to NAVD88, in feet.

- 200 Year Water Surface Elevation: El. +33.5

When the bridge is in the down position, the vertical clearance at the navigation channel is measured from design high water to the bottom of low steel. When the bridge is in the up position, vertical clearance at the navigation channel is measured from design high water to the bottom of the navigation light. The Navigational Channel Width was based on discussions with the United States Coast Guard (USCG). The provided navigation clearance is square to the navigation channel and therefore has 0 degree skew.

- Minimum Vertical Clearances
  - 3'-0" above 200 year water surface elevation in closed position
  - 56'-1" above 200 year water surface elevation in open position
- Minimum Horizontal Clearance:
  - 170'-0" Navigational Channel Width

The provided clearances over the navigation channel, resulting from the combination of roadway vertical profile and structural depth, are shown on the respective General Plan and Elevation (GP&E) sheet for each alternative, included in Appendix A.

Loads and Forces

- Load combinations will be applied per AASHTO LRFD or AASHTO Movable Bridge Design Specifications, as appropriate.
- Vehicular Live Load
  - Four design lanes between barriers (including area of vehicle lanes, bicycle lanes, and shoulders)
  - Pedestrian walkways are designed for a design lane (not concurrently with the pedestrian loading).
  - HL-93 Live Loading, per AASHTO LRFD and California P15 per California Amendments to AASHTO LRFD.
  - Multiple Presence Factors and Dynamic Load Allowance are applied per AASHTO LRFD and California Amendments to AASHTO LRFD. The pedestrian walkway will be considered as a "loaded lane" when determining the multiple presence factor.
  - Pedestrian Loads are applied per AASHTO LRFD
    - The applied Pedestrian Load on the pedestrian walkways will be 0.075 ksf.
  - There are no Special Design Vehicles.
    - It was assumed that the future streetcar loading will be less or equivalent to the HL-93 design load. This will be verified in the next stage of design.
    - Any special design vehicles that may be used on the pedestrian walkways will be investigated in the next phase of design.
  - Longitudinal Loads are applied per AASHTO LRFD and California Amendments to AASHTO LRFD. Since this bridge may be used as part of an emergency evacuation route, the longitudinal loads will be applied assuming uni-directional traffic in the travel lanes (4 design lanes, including the bicycle lanes and the vehicular lanes).
  - Fatigue Loading
    - Fatigue design truck as specified in AASHTO LRFD.
    - Fatigue permit truck from California Amendments to AASHTO LRFD.
- Dead Loads
  - Unit weight of materials is per AASHTO LRFD
- Seismic Design
  - In further design stages, the seismic design philosophy will be determined in coordination with the project Geotechnical Engineers.
  - A detailed multi-mode spectral analysis is envisioned to be required in the design of the new Broadway Bridge superstructure and substructure. The *Caltrans Seismic Design Criteria* as well as the *AASHTO Guide Specification for LRFD Seismic Design* will be referenced as required.
  - The *Broadway Bridge Feasibility Study Geotechnical and Constructability Considerations* technical memorandum notes that the bridge site is prone to liquefaction. This will be further investigated, and appropriate measures will be taken during the design of the new bridge.
- Scour
  - The *Broadway Bridge Feasibility Study Preliminary Hydraulics Study* technical memorandum notes that the river bottom is potentially susceptible to scour. The depth of scour will be revisited and applied at each applicable load case as specified in AASHTO LRFD with assistance from the team's geotechnical engineers.
- Vessel Collision
  - For this report, conservative assumptions were made to determine an initial size of the fenders.
  - In future design phases, the design vessel collision force will be determined in greater detail per AASHTO LRFD and the AASHTO Guide Specifications for Vessel Collision Design of Highway Bridges for the piers located in the Sacramento River.

Foundations

The bridge alternatives in this report assume that the piers will be founded on deep foundations.

Streetcar Information

The bridge alternatives will be designed with the capability to carry streetcar traffic. The streetcar infrastructure will not be included when the bridge is initially constructed, although allowance will be included to add streetcars to the structure sometime in the future. The relative effort of adding a streetcar will be considered for each bridge alternative. An assumption of the additional dead load required for the future streetcar modifications was accounted for in the conceptual design of the movable bridge alternatives.

Since the cross section of the new bridge does not allow sufficient width for streetcars to occupy lanes separate from vehicular traffic, an embedded track would need to be implemented. Embedded track is a commonly used system for light rail transit in urban areas where the rail is encased, except for the top of the rail, within pavement. There are several different types of embedded track systems that can be used and several factors that need to be taken into consideration in the selection and design of the system. Some of the different factors that vary for a given system include rail type, track type, supporting structure type and support framing system. For the purpose of comparing the implementation of the streetcar modifications, the following track system, structure type, and details were assumed:

- Rail Type: Groove Rail
- Track Type: Rail directly fixed to a steel support
- Supporting Structure Type: Stringers configured and spaced to support rail tracks
- Overhead Contact System: Streetcars with on-board storage (batteries) will be used, eliminating the need for an overhead contact system for full length of the bridge
- Drainage: Flangeway drains will only be required at expansion joints

Discontinuities in the embedded rails will be required for the movable bridge alternatives. This discontinuity is accommodated by using a mitered rail as shown in Figure 4. Typically the mitered rail is offset from the expansion joint to minimize the stress and differential deflection of the two sides of the mitered rail. On the movable spans, additional consideration would need to be accounted for in the design to ensure that the mitered rail extension on the movable span would not interfere with fixed obstructions such as tower members for the vertical lift alternatives, the deck slab under the counterweight for the overhead counterweight bascule alternatives or the deck slab over the counterweight for the underdeck counterweight bascule alternatives. Rail lifts would be required for the swing spans to lift the rails above the approach obstructions before the span could open. The vertical lift and swing alternatives would require mitered rail joints at both ends of the movable span and bascule alternatives will require mitered rail joints near the pivot locations at the piers and at the centerline of the movable span assuming a two-leaf bascule.

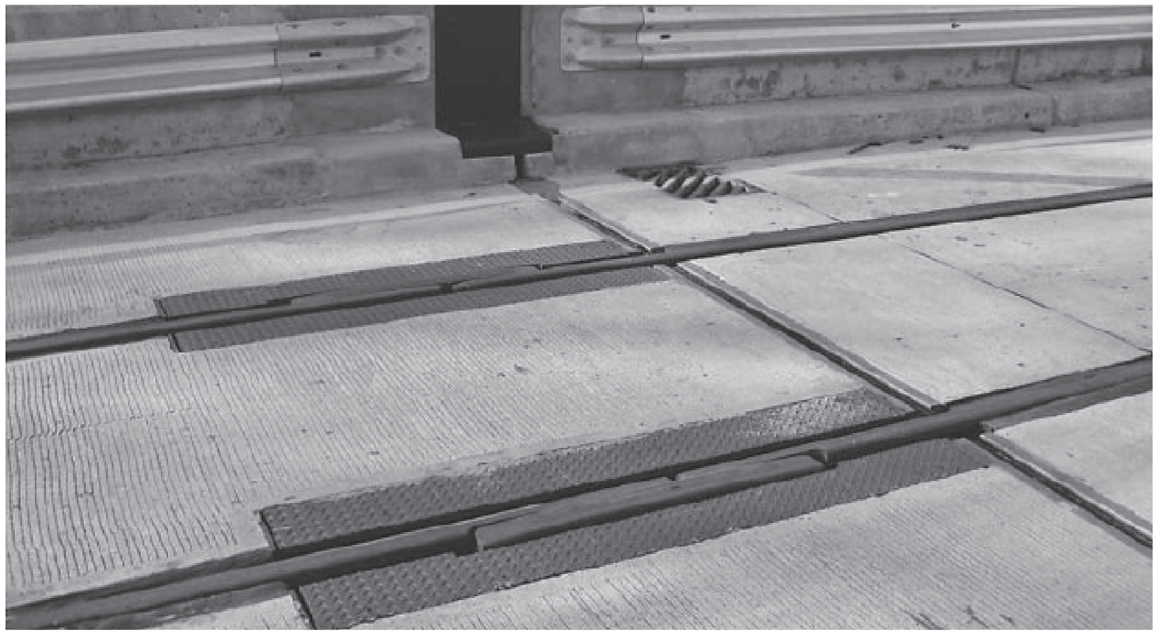


Figure 4 – Embedded Track Miter Rail

To increase the number of possible streetcar installation methods that may be used, any structure with overhead components, i.e. through truss upper bracing or tower bracing, will be designed to provide sufficient vertical clearance if an overhead contact system would need to be installed on the bridge. Although the cost analysis will assume the streetcar will be powered by on-board energy storage for the Broadway Bridge, it was decided to include the allowance for this additional clearance required for the possible installation of an overhead contact system.

Per AASHTO LRFD Bridge Design Specifications, 7th edition, Article 2.3.3.2, the vertical clearance from the roadway to the overhead cross-bracing of through-truss structures should not be less than 17'-6" for highway traffic. However, since the bridge is expected to carry mixed rail and highway traffic in the future, further considerations for the rail clearance need to be considered. For this study, it was assumed that the minimum vertical clearance at the centerline of the roadway to the bottom of the lateral system is 19'-9". This was determined to be a conservative value based on other existing examples of light rail on bridge structures. This dimension will continue to be developed in future design phases

III. Deck Types

A. Deck Type Descriptions

Five deck types were evaluated to determine the relative cost and weight of different floorsystem alternatives. These five types were selected to fulfill the need to minimize the weight of the movable span. The deck types evaluated are as follows:

- Reinforced Lightweight Concrete deck supported by stringers and floorbeams
- Half Filled Grid deck supported by stringers and floorbeams
- Exodermic deck supported by stringers and floorbeams
- Orthotropic deck
- Open Grid deck

Deck types such as normal weight concrete deck supported by stringers and floorbeams and full filled grid deck supported by stringers and floorbeam were not evaluated in this study as they do not fulfill the need to minimize the weight of the movable span. Deck types such as aluminum decking were not evaluated due to the higher initial cost.

A reinforced concrete deck is designed to be composite with the supporting stringers and floorbeams (Error! Reference source not found.). To minimize the weight of the deck, lightweight concrete is utilized. The initial construction cost of a reinforced concrete deck is lower than that of all of the other deck types; however, this type of deck results in the largest weight of all of the other deck types. The increase in weight for a reinforced concrete deck would subsequently increase the weights and costs of bridge members that support the deck. Ultimately, this would also increase the size of the counterweight and the cost of the mechanical system.

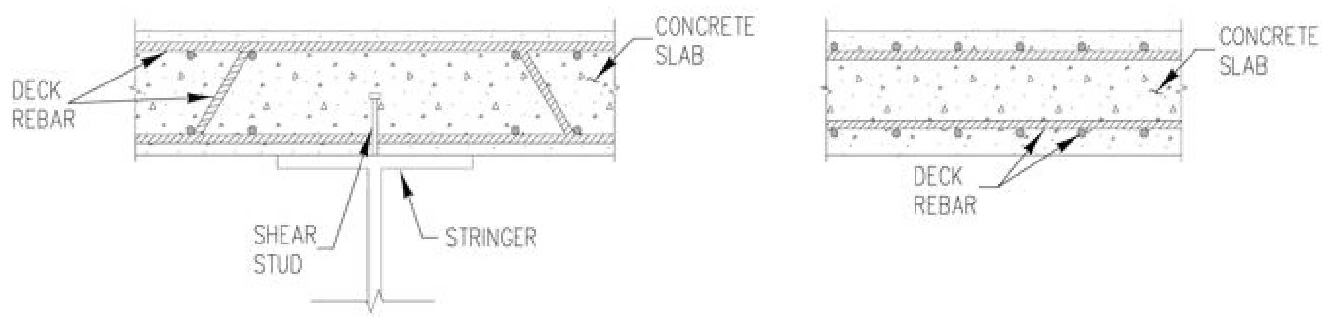


Figure 5 – Lightweight Reinforced Concrete Deck Cross Sections

Half filled grid decks are comprised of a metal grid deck with concrete fill in the top half of the grid (Figure 6). In order to protect the grid from corrosion, an additional concrete overfill is provided above the grid. The metal grid deck consists of rolled I-beam shapes spanning in the primary direction and cross bars spanning in the secondary direction. If additional capacity is necessary, supplementary bars can also be included in the primary direction. In comparison to a traditional reinforced concrete deck, a half filled grid deck system reduces weight by eliminating concrete from the bottom of the deck. The concrete in the bottom of the deck does not contribute to the flexural capacity under positive bending moment, and therefore is not necessary. The initial construction cost of a half filled grid deck is, on average, greater than that of a reinforced concrete deck.

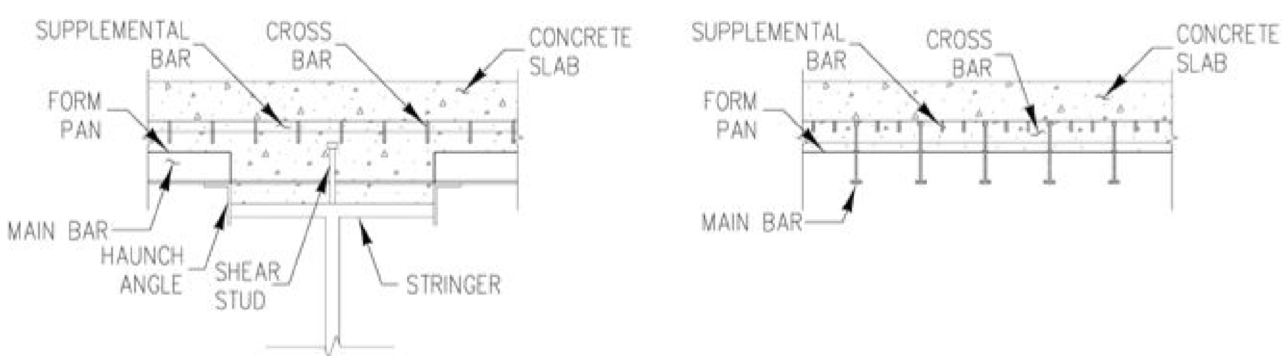


Figure 6 – Half Filled Grid Deck Cross Sections

An Exodermic deck (Figure 7) consists of a reinforced concrete slab that is cast on top of an unfilled metal grid deck. The reinforced concrete slab and the unfilled metal grid deck are made composite with one another. The metal grid utilizes standard WT sections as the primary members spanning between stringers or floorbeams. Distribution bars span in the secondary direction and support a form pan. The form pan is what supports the reinforced concrete slab. When subjected to positive bending moment, the WT sections are in tension and the concrete slab is in compression. When subjected to negative bending moment, the concrete slab reinforcement is in tension and the WT sections are in compression. This configuration attempts to maximize the tensile strength of the steel and the compressive strength of the concrete in order to create an efficient deck system. An Exodermic deck weighs less than a traditional reinforced concrete deck; however, an Exodermic deck has an increased initial construction cost.

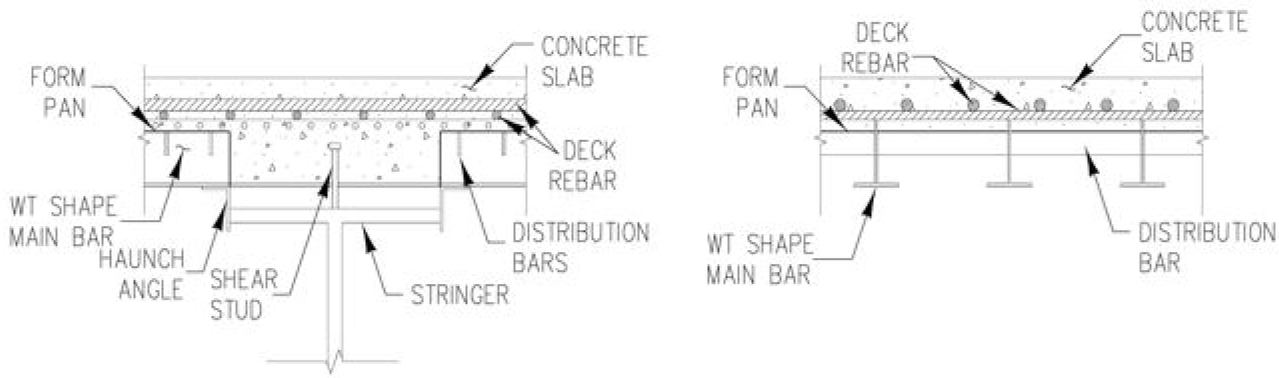


Figure 7 – Exodermic Deck Cross Sections

An orthotropic deck (Figure 8) is made up of a thin steel plate that is supported and stiffened by a series of ribs. The ribs span parallel to the direction of traffic and are supported by transverse floorbeams. The ribs are made to be integral with the floorbeams. To provide sufficient skid resistance and protect the steel deck from corrosion, a wearing surface, commonly a bituminous mix or epoxy resin, is placed on top of the steel deck. An orthotropic deck weighs less than a traditional reinforced concrete deck and can also be installed more rapidly than a traditional reinforced concrete deck. However, an orthotropic deck has a high initial construction cost. Historically, orthotropic decks have had various potential limitations, such as fatigue cracking and premature failure of the wearing surface, although these issues can be addressed with proper design using the current AASHTO Specifications.

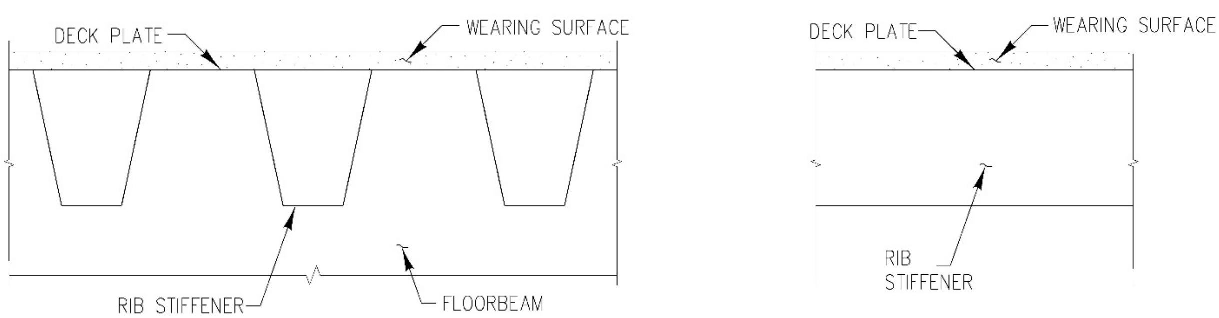


Figure 8 – Orthotropic Deck Cross Sections

An open grid deck is composed of rolled I-beam shapes spanning in the primary direction, with cross bars spanning in the secondary direction. An open grid deck is generally the lightest deck option and has the lowest initial construction cost when considering items such as decreased counterweight size and machinery size. However, the ride quality provided by the open surface of an open grid deck is typically not preferred, as the open grid deck does not provide a solid surface for the vehicular traffic, pedestrians, or bicyclists crossing the bridge. Specifically, for pedestrians, the open grid surface provides an uncomfortable surface for walking. For these reasons, it was determined that the positives do not outweigh the negatives, and therefore, it was decided to not pursue an open grid deck.

B. Deck Comparison

The deck types were investigated to determine the weight and cost of each floorsystem alternative.

The weight and cost of the entire floorsystem, which consists of the deck, stringers, and floorbeams, was determined for each alternative. Table 1 presents the relative weight and cost of each floorsystem alternative. For comparison purposes, a floorsystem comprised of a reinforced lightweight concrete deck for both the roadway and pedestrian walkway was taken as the baseline alternative. Consequential weight and cost variations associated with changes in the floorsystem type (e.g., counterweight, superstructure) are not included in the comparison.

Floorsystem Deck Type	Relative Weight	Relative Cost
Lightweight Concrete	1.00	1.00
Exodermic	0.91	1.05
Half Filled Grid	0.97	1.23
Orthotropic	0.64	1.54

Table 1 – Floorsystem Deck Type Comparison

A comparison of the floorsystem alternatives from Table 1 shows that an orthotropic deck for both the roadway and pedestrian walkway floorsystems results in the lowest weight. However, this type of deck would cost about one and half times as much as any of the other floorsystem alternatives. Due to the high cost, an orthotropic deck is not considered a viable option for the bridge floorsystem.

A floorsystem comprised entirely of a half filled grid deck would result in a lighter floorsystem in comparison to a reinforced concrete deck. However, similar weight savings can be achieved with an Exodermic deck at a considerably lower cost. Therefore, a half filled grid deck is not considered a viable option.

The remaining deck types, reinforced lightweight concrete and Exodermic, are considered to be viable options. A floorsystem comprised entirely of a reinforced lightweight concrete deck would result in a lower cost but a higher weight. A floorsystem designed with an Exodermic deck would result in a lighter but more costly floorsystem relative to a reinforced lightweight concrete deck.

The reinforced lightweight concrete and Exodermic deck alternatives were investigated in greater detail in order to determine the most viable option. Due to the cross-sectional configuration of the movable span, different deck types could be utilized for the roadway and pedestrian walkway floorsystems. Therefore, the roadway and pedestrian decks were evaluated separately to allow for different combinations of deck types. In addition, rolled and built-up stringer sections were investigated for the pedestrian walkway floorsystem, in order to compare the weight savings associated with built-up stringers. The possibility of future streetcar traffic carried by the bridge was also considered in the comparison of the concrete and Exodermic deck types. It was assumed that the bridge will carry two lanes of streetcar traffic that will be shared with vehicular traffic. The comparison of the reinforced lightweight concrete and Exodermic deck alternatives is presented in Table 2. A floorsystem with a reinforced lightweight concrete deck with rolled stringers, for both the roadway and pedestrian walkway floorsystems, was taken as the baseline alternative. The relative weights and costs reported do not include rails, rail connections, or construction costs associated with modifying the bridge to accommodate streetcars.

Roadway Floorsystem Deck Type	Pedestrian Walkway Floorsystem		Relative Weight	Relative Cost
	Deck Type	Stringer Sections		
Lightweight Concrete	Lightweight Concrete	Rolled	1.00	1.00
Lightweight Concrete	Lightweight Concrete	Built-up	0.99	1.03
Lightweight Concrete	Exodermic	Rolled	0.98	1.00
Lightweight Concrete	Exodermic	Built-up	0.97	1.04
Exodermic	Exodermic	Rolled	0.91	1.01
Exodermic	Exodermic	Built-up	0.90	1.05

Table 2 – Comparison of the Lightweight Reinforced Concrete and Exodermic Deck Alternatives

The comparison of the pedestrian walkway floorsystem alternatives with rolled and built-up stringer sections, shown in Table 2, results in slight changes in relative cost and weight. Built-up stringers for the pedestrian walkway result in a minimally lighter floorsystem, but the cost per stringer is slightly higher in comparison to rolled stringers. The weight savings associated with built-up stringers could allow for other bridge members to be smaller and lighter. However, while built-up stringers are lighter than rolled stringers, the weight savings are negligible in comparison to the entire floorsystem.

Evaluation of the various combinations of roadway and pedestrian walkway deck types from Table 2 shows that a floorsystem comprised entirely of an Exodermic deck results in the lightest floorsystem alternative. A floorsystem comprised entirely of an Exodermic deck results in a small increase in cost in comparison to a lightweight concrete deck floorsystem. A floorsystem comprised entirely of a lightweight concrete deck would result in the lowest cost but the highest weight. The weight savings associated with the Exodermic deck would also reduce the weight of the counterweight and mechanical systems, which would ultimately reduce the overall cost.

When evaluating the floorsystem alternatives, the ability of the deck alternatives to carry future streetcar traffic was also considered, for both the lightweight reinforced concrete deck and the Exodermic deck. For both deck types, the relative weight and cost of the floorsystem would be larger if initially designed for streetcar traffic, due to larger stringer sections that would be needed to carry the streetcar rails. However, it should be noted that delaying the design of the floorsystem for streetcar traffic will incur future rehabilitation cost and weight. The additional dead load associated with a future streetcar will need to be accounted for in the design of the structural members that support the floorsystem regardless of when the floorsystem is capable of carrying streetcar traffic. The constructability of each deck type with streetcar rails was also accounted for when comparing the floorsystem alternatives. Figure 9 shows an example of a streetcar rail directly fixed to a supporting stringer with a lightweight reinforced concrete deck and Exodermic deck, respectively. For both deck types, the stringer top flange width would have to be increased to accommodate the rail and necessary connections. In addition, prior to the rails being installed, “filler” deck sections would be required within the void space of the future rail locations. For a lightweight reinforced concrete deck this space could be filled with additional concrete or grout until the streetcar is implemented. Once the streetcar is implemented, the “filler” could be removed by mechanical or hydro demolition techniques. For an Exodermic deck, the void space could be occupied by a separate fabricated Exodermic deck section, which would be bolted to adjacent deck sections until the streetcar rails are added. It is anticipated that the Exodermic “filler” section would be easier to accommodate the streetcar rail construction than the lightweight reinforced concrete “filler” section.

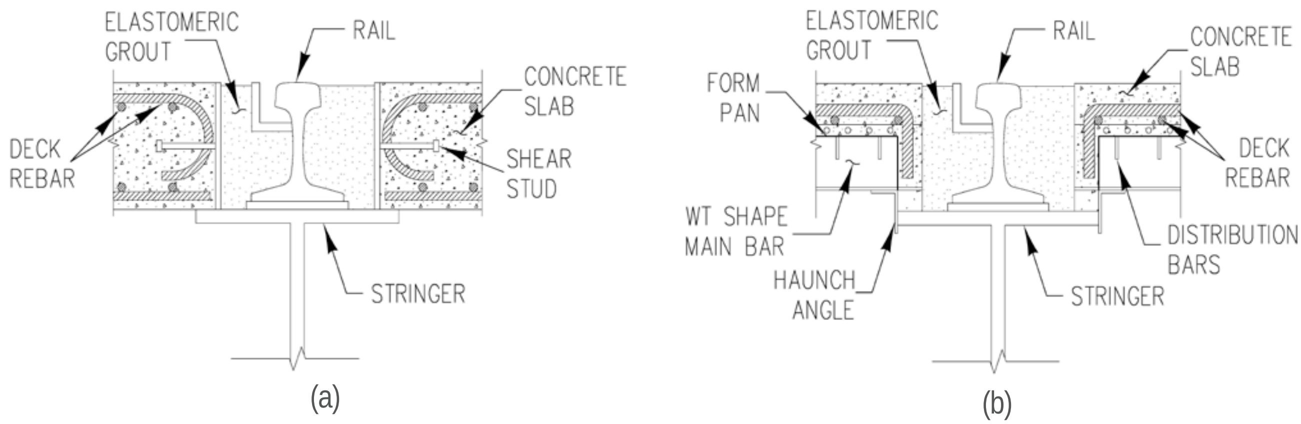


Figure 9 – Example of direct fixation rail for a (a) concrete deck and (b) Exodermic deck

C. Recommendation

The recommended deck type for the Broadway Bridge is an Exodermic deck system. This deck type provides a preferred ratio of weight to initial construction cost of the deck types considered. The Exodermic deck system is the lowest weight deck type aside from the orthotropic deck and has a more reasonable initial construction cost associated with it. The cost of an Exodermic deck system is slightly higher than that of a lightweight reinforced concrete deck system (5%). However, using an Exodermic lower weight floorsystem will allow for reductions in the supporting steel, counterweight, and mechanical components, which will ultimately lower the overall project cost. In addition, the Exodermic deck is capable of accommodating the implementation of a streetcar system with limited construction requirements and user delays.

IV. Movable Bridge Type Alternatives

A. Introduction

The scope for this study was to identify and comparatively analyze differing bridge solutions that may be possible for the new Broadway Bridge project. Representative cost estimates were calculated for each viable option. The different movable bridge types considered are:

- Bascule Span
- Vertical Lift Span
- Swing Span

Within each movable bridge type, several alternatives were selected for comparison. Each alternative is described in more detail in the following sections.

Each alternative will require additional approach structures on either side of the main, movable span. Since this study focused on the movable span, the details of these approach structures were not included in this study.

All alternatives include a typical operator's house – a separate building located on the bridge where a bridge operator would control the movement of the span.

For all alternatives the navigation channel width is assumed to be 170'-0" for Alignments A and B, 180'-0" for Alignment C, and 240'-0" for Alignment D. An emphasis was placed on providing bridge alternatives that maintain a "neighborhood friendly" river crossing.

B. Bascule Span Alternatives

One option for the movable span of the Broadway Bridge is a bascule span. Bascule bridges operate by rotating about a horizontal axis. This axis may be fixed (as in a trunnion type bascule) or free to translate (as in a rolling type bascule).

B.1 Bascule Span Configurations

Trunnion Bascule Bridge

A trunnion bascule bridge rotates around an axle, or trunnion, as the span is raised. The required span length of a trunnion bascule bridge would be somewhat longer than other movable span options. This additional length is due to the offset of the trunnions away from the channel side of the pier to allow room for the trunnion supports and to allow the span to open to permit a 56 ft 1 in tall channel along the entire channel width. This additional required distance adds to the total length of the movable span.

Rolling Lift Bascule Bridge

A rolling lift bascule bridge raises the span by rolling on a track. Two examples are included in Figure 12 and Figure 13. These bridges include overhead counterweights, although an underdeck counterweight could also be used with a rolling lift span. The rolling tread is provided with pintles or lugs which prevent horizontal slippage while the span rolls on the track. The use of a rolling bascule generally helps reduce the total span length of the movable span due to the span both translating and rotating as it opens. Because of this translation, the required span length for a rolling bascule is somewhat shorter than the corresponding span length for a trunnion bascule.

Overhead or Underdeck Counterweight

Bascule bridges can be constructed with the counterweight either suspended above the deck level (overhead counterweight) or placed below the deck level (underdeck counterweight). To use an underdeck counterweight at this location, a large box pier would need to be built to enclose the required counterweight below the deck level to keep the counterweight out of the water when the bridge is opened. This bascule pier may become quite large, and its effect on river hydrology will need to be considered. Traditionally, the bascule leaf superstructure would be placed under the roadway, in a deck girder/truss arrangement. Two examples of a structure with underdeck counterweights are the Elizabeth City Bridge in Elizabeth City, NC (Figure 11) and the South Market Street Bridge in Wilmington, DE (Figure 12).

Figure 10 – Elizabeth City Bridge, Elizabeth City, NC

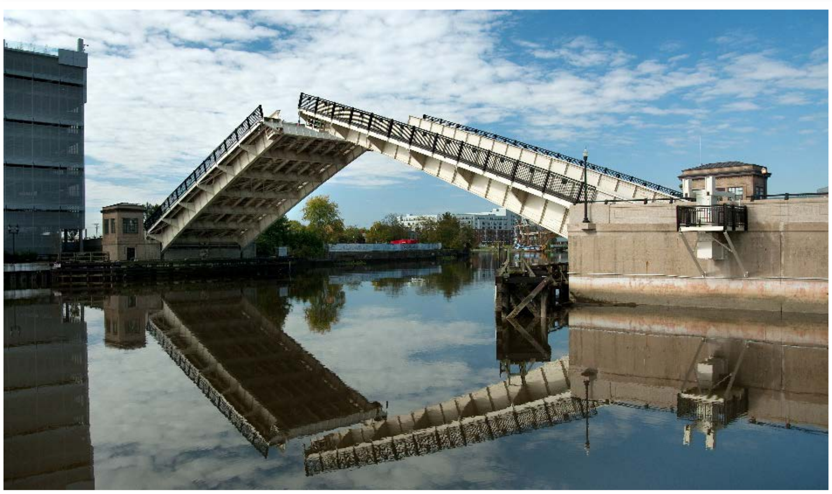


Figure 11 – South Market Street Bridge, Wilmington, DE

With an overhead counterweight, a through truss or through girder arrangement could be readily used for the bascule span. This would be beneficial for the Broadway project due to the limited available under clearance. The depth from the top of deck to the bottom of the structure would be minimized with a through-truss structure, which would allow for a lower vertical profile. This will in turn decrease the grade along the length of the structure, making it friendlier to pedestrians.

A large box pier is not required to encase the counterweight for an overhead counterweight. The bridge could be supported on drilled shafts or concrete piers which should have less impact to the surrounding river. The counterweight traditionally consists of a large block of concrete suspended over the travel lanes. Two examples of a structure with overhead counterweights are the Market Street Bridge in Chattanooga, TN (Figure 12) and the Great Bridge Bridge, Chesapeake, VA (Figure 13). Although, an overhead counterweight would increase the seismic forces that may need to be resisted by the supporting structure, and the foundation and pier would need to be designed accordingly. This is due to the large mass of the counterweight being supported at a higher elevation than that of an underdeck counterweight.

Figure 12 – Market Street Bridge, Chattanooga, TN

Figure 13 – Great Bridge Bridge, Chesapeake, VA

Fully-Counterweighted or Partially-Counterweighted

The bascule span alternatives considered included fully-counterweighted alternatives as well as partially-counterweighted alternatives. As the name describes, the fully-counterweighted alternatives included large counterweights that almost completely balanced the weight of the span. (Some imbalance is built into the system to keep the span in the down position under traffic.) Traditionally, large movable spans are fully-counterweighted to minimize the force required to move the span and therefore minimize the size of the machinery.

The partially-counterweighted bascule span would have a smaller counterweight, which may lead to a more aesthetic, streamlined structure. Additionally, decreasing the mass of the counterweight will decrease the seismic forces that may need to be resisted by the supporting structure. By only partially-counterweighting the span, larger forces are required to lift the span leading to larger machinery. The partially-counterweighted options included in this report were assumed to be operated by hydraulic cylinders. A discussion of different operating systems is included in later sections of this report.

Bascule Alternatives

Two bascule bridge options were considered for this report. One option is a two leaf simple trunnion bascule span using a deck girder superstructure. The required girder depth for this bridge type ranges from 6 ft at the toe to 12 ft at the bearing. Each leaf will be approximately 115 ft long, 120 ft long, or 150 ft long for Alignments A/B, Alignment C, and Alignment D, respectively. The width of each leaf will be 83 ft. A typical cross section of a deck superstructure is included as Figure 3. A sketch of a conceptual deck girder system is included in Appendix A as Alternatives A and B. If a bascule bridge type is chosen for further refinement, the aesthetics of this bridge type will be revisited.

The second viable bascule option is a two leaf rolling lift bascule span using a through truss superstructure. Trusses are typically more complex to construct, as well as more complex to inspect and maintain, as opposed to girders. For Alignments A and B, each leaf would be approximately 129.25 ft long (Alternative C-1) or 103 ft long (Alternative C-2) with a width of 90.5 ft. For Alignment C, each leaf would be approximately 135.5 ft long (Alternative C-1) or 108 ft long (Alternative C-2) and for Alignment D, each leaf would be approximately 161.75 ft long (Alternative C-1) or 138 ft long (Alternative C-2). A sketch of the cross section is included in Appendix A as Alternatives C and D. Similar to the deck girder option, additional refinement will occur if a bascule girder span is decided to be the most feasible structure type for the Broadway Bridge project.

Alternatives C-1 and C-2 have been included in the Appendix as two possible arrangements of a rolling lift bascule spans. Alternative C-1 includes a live load support underneath the first panel point, adjacent to the navigation channel. This alternative allows for a smaller rack frame at the expense of a slightly longer span. Alternative C-2 provides live load reaction with an uplift support at the rack frame. This alternative allows for a shorter span length at the expense of a much more robust rack frame support. The construction cost and long term maintenance effort for both alternatives are similar, and both options are viable for the Broadway Bridge.

B.2 Mechanical and Electrical System Options

Bascule bridges are commonly driven by electric motors, which transmit torque through a series of gear reductions to raise and lower the span. Alternatively, hydraulic cylinders that are mounted between the pier and the bascule girder can directly drive the span simply by extending and retracting.

Electro-Mechanical Drive

Traditional electro-mechanically operated bascules consist of electric motors, brakes, couplings, gear reducers, shafts, bearings, final pinions, and rack gears. The final pinion engages with the rack gear to rotate the bascule girder about the fixed trunnion.

Electro-mechanical drive motors are controlled by a variable speed drive. These require a higher level of expertise to maintain over other drive options. Variable speed drives provide more information for troubleshooting motor problems, but replacement drives will require setting parameters to match the installed settings in the drive which may add difficulties in replacing the drive with a drive from another manufacturer.

Advantages of Electro-Mechanical Drive include:

- Individual drive components are accessible for inspection and troubleshooting
- Drive system components are more modular for replacement and rehabilitation
- Variable speed drives provide more information for troubleshooting motor related problems

Disadvantages of Electro-Mechanical Drive include:

- Installation and alignment of gears is labor intensive
- More moving parts requiring regular lubrication and creating a potentially more dangerous working environment
- Replacement drives require parameter setup which is compounded if replacement drive is from a different manufacture than the original

Hydraulic Cylinder Drive

Hydraulic cylinder operated bascules consist of electric motors, pumps, couplings, hydraulic power units, valves, hoses, hydraulic cylinders, and cylinder connections. Hydraulic pressure builds on the bore side of the cylinder creating a pressure differential, which causes the cylinder to extend, rotating the bascule girder about the fixed trunnion or roll on the track.

Motors could be controlled from a motor starter. Partially counterweighted lift spans will require larger, more complex motors and controls. They require less expertise than a variable speed drive, and less troubleshooting information; however, they do still require a small amount of parameter setting.

Advantages of Hydraulic Cylinder Drive include:

- Typically more compact than electro-mechanical systems
- HPUs can be housed in a convenient location and hydraulic lines run to the cylinders
- Components can be tested in the shop and installed with minimal field alignment
- Typically less expensive than electro-mechanical systems
- More off-the-shelf components
- Simpler motor starter

Disadvantages of Hydraulic Cylinder Drive include:

- Hydraulic working fluids are often temperature sensitive
- Hydraulic expertise is required for troubleshooting
- HPU and hydraulic cylinders are large and may require special access for installation/removal
- Some hydraulic working fluids pose an environmental hazard
- Control adjustments are more difficult
- Less energy efficient
- Less troubleshooting information available from motor starter

Both drive systems are carried forward to the cost estimates of the bascule bridge alternatives. The hydraulic drive system is used for both partially counterweighted alternatives, while the electro-mechanical drive system is used for both fully counterweighted systems.

Control System

A control system is required to ensure safety interlocking enforcement, and control of the movement of the span. There are two viable alternatives to achieve this control, as described below.

PLC Control

A Programmable Logic Controller (PLC) system consists of a digital electronic processor with inputs and outputs that interface with the rest of the electrical control system components. The central processor is programmed specifically to control the bridge operations and can record and store the operational conditions of major electrical components, and continuously display the status of the bridge.

Advantages of PLC Control include:

- Logic is programmable allowing the bridge operating control logic to be easily changed or adjusted by simply modifying the PLC program without the need for costly wiring changes.
- All bridge operations can be logged and later reviewed
- Bridge status can be displayed in a graphical format and can utilize a touch screen
- More information is available to maintenance personnel to lessen the troubleshooting time
- Inputs and outputs (I/O) in the machine rooms can be connected to a nearby cabinet and then communicated back to the processor over a single fiber optic cable reducing the number of electrical conductors and improving reliability
- Upgrading a PLC system is relatively simple.

Disadvantages of PLC Control include:

- Maintenance personnel need to have training and expertise with PLCs to make program changes, or utilize a specialty contractor to provide these services
- Replaceable components of the PLC system are higher cost than relays and must be compatible with the existing system and usually by the same manufacturer
- Life cycle of the PLC system is typically 20-25 years

Relay Control

A relay control system consists of individual relays wired together to perform the control logic and interconnected with the other control system components to operate the bridge.

Advantages of Relay Control include:

- Easier to trouble shoot for any electrician with industrial control experience
- Typically less vulnerable to lightning or voltage spikes and surges

- Relays can be replaced individually and with any manufacturers models with the same electrical characteristics

Disadvantages of Relay Control include:

- Changes to bridge operating logic require rewiring the control and possibly additional relays
- Relay control typically requires more space, and larger cabinets
- Significantly increased amount of interconnecting wiring is required

Both the PLC control system and the relay control system are suitable for all the bascule alternatives being considered. But the PLC system offers many advantages in terms of its adaptability to different situations, as well as its ability to store bridge operating data for the City's use in maintenance and operations logging and trending. Therefore, a PLC control system is the recommended bridge control system.

Bascule-to-Bascule Electrical Cable System

Electrical connectivity is required between both bascules. There are two viable alternatives to achieve this connectivity for the major power and control needs, as described below.

Aerial Cable

Aerial cables are not common on bascule bridges due to limiting the vessel height that can use the channel, but as this location has a defined height limitation based on the nearby fixed bridge crossing, aerial cables are a viable system for the Broadway Bridge. A support structure is required to obtain the height required for the aerial cables to cross the channel which would impact the aesthetics to the final bridge. The aerial cable system itself consists of a system of electrical cables strung across the channel, attached to one or more steel messenger wires for support. It provides for the electrical connectivity between the two bascule piers.

Advantages of Aerial Cables include:

- Replacement is less difficult and much less costly than submarine cables
- Generally the least expensive cable system

Disadvantages of Aerial Cables include:

- Require more maintenance than submarine cables.
- Requiring a support structure and crossing above the channel, the aerial cables may be considered visibly obtrusive
- Aerial cables are exposed to the weather and have a shorter service life than submarine cables.

Submarine Cable

A submarine cable system is typically a group of special armored electrical cables buried below the river bottom, running from one bascule pier to the other, thereby providing the connectivity between the two piers.

Advantages of Submarine Cables include:

- Require the least maintenance, typically having a service life of up to 40 years
- Submarine cables are not visible, thus the aesthetics of the bridge are not affected

Disadvantages of Submarine Cables include:

- Installation is by far the costliest, perhaps up to $1 million more than the other cable systems, and requires permitting for the trenching in the river bottom

- Submarine cable replacement is the most difficult, usually involves simply installing new cables in a new trench in the river bottom

For aesthetic considerations, the expensive submarine cables would be most advantageous. In terms of the overall bridge cost, the additional cost of the submarine cables is acceptable as they provide a longer service life, lower maintenance cost, and are more aesthetic pleasing. Therefore, the submarine cable system is recommended.

B.3 Summary of Bascule Span Alternatives

The summary of bascule span alternatives types that will be considered for this study are as follows:

- Alternative A – Fully Counterweighted Two Leaf Deck Bascule Girder
- Alternative B – Partially Counterweighted Two Leaf Deck Bascule Girder
- Alternative C – Fully Counterweighted Two Leaf Rolling Bascule Truss
- Alternative D – Partially Counterweighted Two Leaf Rolling Bascule Truss

C. Vertical Lift Span Alternatives

A vertical lift span is an additional viable option for the new Broadway Bridge. Vertical lift bridges are well represented in the surrounding area of the project, for example the Tower Bridge is located nearby upstream of the proposed Broadway Bridge location. Vertical lift bridges have a span that is lifted vertically to permit passage of vessels beneath it. This bridge type would have two towers – one on either side of the lift span. A counterweight would be suspended in each tower, with each counterweight weighing approximately ½ of the weight of the span. As the bridge is raised, the counterweights are lowered.

Vertical Lift Bridges are typically used when a longer movable span is required than can reasonably be provided by a bascule span. As the required span length combined with the out-to-out width is approaching the practical limit for a double leaf bascule span, a vertical lift bridge is a viable option for the new Broadway Bridge.

C.1 Vertical Lift Span

Because of the high and low profile options, both through and deck lift span structures are viable. A deck structure, which would consist of a deck girder superstructure, could only be used with the higher profile. For the lower profile, there would not be sufficient depth for a deck girder superstructure but a through truss or through girder lift span would be viable options.

The required length of a vertical lift bridge is approximately 199’-0” for Alignment A and B, 209’-0” for Alignment C and 269’-0” for Alignment D. These span lengths allow the bridge to span the required navigation channel as well a fender system. It was assumed that a separate, independent fender system would be constructed to protect the bridge piers, which requires additional span length.

For this report two different types of vertical lift spans will be considered – a through truss span and a through girder span. A through girder span was selected over the deck girder option due to its ability to be used with either the higher or lower profile. It was assumed that the vehicular and bike lanes would be located inboard of the through girders and the sidewalks would be located outboard of the through girders. The lifting location was assumed to be at the ends of the girders.

Through truss spans can consist of several different framing configurations, including constant depth and haunched trusses. A haunched truss is deeper at the center of the span than the ends. The advantage of the haunched depth is to provide additional strength but is not required for spans of this length. Constant depth trusses eliminate the need for complicated geometry and greatly simplify fabrication. The members can consist of I-shape members or box shape members; however, I-shape members are preferred due to easier fabrication as long as a practical I-shape member size is achievable. The through truss used for this report is constant depth and uses I-shaped members.

C.2 Tower Types

Like the vertical lift span itself, there are options available for the design of the vertical lift tower structures. Vertical lift tower structures are typically constructed of either steel or concrete. Each of the two material types are discussed below, including the different types of towers that are commonly constructed out of each material.

With all the tower types discussed below, access will be provided to the top of each tower. The access will include an elevator, as well as a stairway. The final access location would depend on the final configuration of the tower. If relatively small, slender, and solid tower sections are chosen, the access would be located on the outside of the tower legs. This would make the stairways and elevators visible. If the tower legs are larger and hollow, the stairways and elevators may be able to be placed inside the tower structure, which would create a more streamlined structure.

Steel Towers

Steel towers are the most commonly used type of towers for vertical lift bridges. Vertical lift steel towers are capable of being designed using several different geometric layouts. Three conventional types of steel vertical lift towers include:

- Steel trussed towers
- Sloped steel trussed towers
- Steel frame towers

Examples of the three types of steel vertical lift towers are the Gilmerton Bridge with steel trussed towers (Figure 15), the Philadelphia Navy Yard Lift Bridge with sloped trussed towers (Figure 16), and the Paulsboro Railroad Bridge with steel frame towers (Figure 17). Modifications or variations are available for each tower type. To provide a more aesthetically pleasing appearance, different bracing configurations, steel cladding, and/or decorative lighting could be implemented.

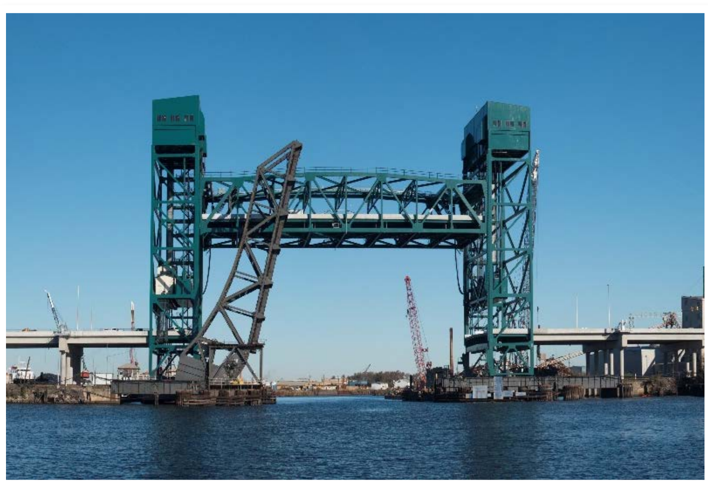


Figure 14 – Gilmerton Bridge, Chesapeake, VA

Figure 15 – Philadelphia Navy Yard Lift Bridge, Philadelphia, PA

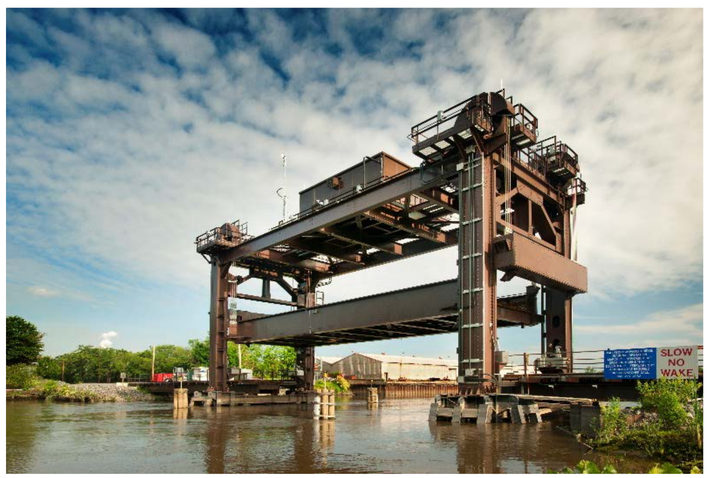


Figure 16 – Paulsboro Railroad Bridge, Paulsboro, NJ

Two steel tower options were considered for this report. The first option considered is a steel frame tower. With this option, the overall height of the towers would be approximately 108 ft, with a tower out-to-out width of 75 ft.

The second steel tower option considered is a steel trussed tower. With this option, the overall height of the towers would be approximately 118 ft, with a tower out-to-out width of 64 ft. Conceptual sketches of both steel tower options are shown in Appendix A as Alternatives F and G.

Concrete Towers

Another option for the vertical lift bridge towers of the Broadway Bridge is to use concrete. Although the use of steel in bridge towers is more prevalent, reinforced concrete is a viable option for this structure. Like the steel vertical lift towers, there are multiple possible arrangements for concrete vertical lift towers. A few possible options include:

- Braced frame
- Two columns per tower connected with top struts
- Four independent towers

Examples of the braced frame concrete vertical lift towers and the two column concrete vertical lift towers connected with top struts are the Bayou Lafourche Bridge (Figure 17) and the Pont de Recouvrance Bridge (Figure 18), respectively. All of the concrete tower types have additional options for constructability, such as cast-in-place reinforced concrete towers and pre-cast post-tensioned concrete tower sections. These options can be considered for additional cost savings and ease of construction. Additionally, the future maintenance requirements for concrete is traditionally less than that of steel, as the towers would not need to be painted.

Figure 17 – Bayou Lafourche Bridge, Larose, LA

Figure 18 – Pont de Recouvrance, Brest, France

Due to the nature of concrete structures, many solutions are available for creating an aesthetic structure. Architectural relief panels or additional shapes could be cast into the faces of the tower. Architectural form liners could be used for adding a pattern to the surface of the towers. Additionally, colors or patterns may be added to the faces of the towers with concrete staining.

For this report, concrete towers consisting of four columns connected with top struts were considered. The overall height of the concrete towers would be approximately 106 ft, with a tower out-to-out width of 117 ft. A conceptual sketch of the concrete tower option is shown in Appendix A as Alternative D.

C.3 Mechanical and Electrical System

Vertical lift bridges are generally categorized into two basic types, span drive or tower drive, according to the arrangement and location of the operating machinery.

Span Drive

Span Drive bridges are vertical lift bridges which are driven by machinery typically housed centrally on the lift span. The machinery raises and lowers the span by pulling itself up and down the towers using wire ropes (operating ropes) that are attached to the tops and bottoms of the towers and wound onto and off of rope drums located on the lift span.

Advantages of Span Drive include:

- One set of machinery, located in central area (on the lift span)
  - Eliminates need for machinery houses at tops of towers
  - Single person emergency operation capability using a single auxiliary gearmotor
- Inherent skew control
  - The arrangement of the operating ropes inherently maintains the lift span in a level state as it raises or lowers.
- Simpler Electrical Controls as compare to Tower Drive
  - No electrical skew control needed, resulting in significantly higher system reliability
  - Significantly simpler control logic makes electrical trouble-shooting easier
  - Both types of controls systems, relay based and digital computerized(PLC), are feasible

Disadvantages of Span Drive include:

- Many Unique Components
  - Operating rope drums, operating ropes, and operating rope tensioning assemblies are unique to span drives and require disciplined inspection and maintenance attention to ensure adequate service life and reliability
  - Increased span weight, due to the machinery on the span. This may increase the number or size of the counterweight ropes, counterweight rope sheaves, and counterweight sheave bearings.
- Lift Span Design and Aesthetics
  - Lift span will be somewhat heavier since it will carry all the machinery and the machinery house

Tower Drive

Tower Drive bridges are vertical lift bridges driven by machinery housed at the top of each tower, usually inside enclosed machinery rooms. The machinery lifts and lowers the span by rotating the counterweight sheaves on the tower tops much like an elevator.

Advantages of Tower Drive include:

- Fewer Unique Components
  - Fewer unique components to maintain and inspect.
- Machinery Enclosed
  - The entire mechanical drive system is enclosed in the covered tower tops, providing protection from the elements for all drive components.
  - Provides better environment for inspection and maintenance.
- Lift Span Design and Aesthetics
  - Lift span can be somewhat lighter since it carries no machinery or machinery house

Disadvantages of Tower Drive include:

- Machinery Located in Two Tower Tops
  - Machinery located at tops of both towers requires maintenance at both locations
  - Emergency operation will require personnel located in both towers simultaneously
- Skew Control Necessary
  - Drive motors in the two tower tops must be electrically synchronized while running to maintain the lift span level within tight tolerances to avoid jamming and damaging the lift span between the towers
  - Skew control issues often reduce the overall reliability of tower drive bridges
- Tower Top Machinery Installation Critical
  - The counterweight rope sheave bearing support girders in the tower tops deflect once the dead load of the span is added to the counterweight ropes, altering the alignment of the bearings. This effect can be estimated and accounted for in initial unloaded alignments, but field realignment after the ropes are loaded will be required.
- More complex electrical control system
  - Control system is more complex than for span drive, generally resulting in lengthier trouble shooting and repair when electrical issues occur
- Rope Creep on Counterweight Rope Sheaves
  - Tower drive bridges typically experience varying degrees of incremental rope slippage (creep) on the sheaves, introducing error into the lift span position and skew measurements, and necessitating periodic manual adjustments to the mechanical couplings for the span position instrumentation located in the tower tops

Both drive systems are carried forward to the cost estimates of the vertical lift bridge alternatives. The girder span alternatives are not easily suitable for a span drive system due to the limited space available under the deck for the machinery, so only a tower drive system was considered for the girder span alternatives. A span drive system is possible for the truss span alternative as the machinery room can be located above or within the overhead truss of the span.

Control System

The choice of between a PLC or relay based control system for a vertical lift bridge is similar to the bascule bridge. Some form of PLC is required to perform skew control for alternatives using a tower drive system. For the same reasons as the bascule alternatives, a PLC system is recommended for all vertical lift alternatives.

Tower-to-Tower Electrical Cable System

Electrical connectivity is required between both towers. There are three viable alternatives to achieve this connectivity for the major power and control needs. The requirements for aerial cables and submarine cables are generally the same as for the bascule alternatives. In place of a dedicated aerial cable support as used for the bascule alternatives, the towers of the vertical lift alternatives can be used to support the aerial cables. A third option, droop cables, is available for vertical lift alternatives as described below.

Droop Cables

A droop cable system consists of cables connected from the tower(s) to the lift span, drooped similar to the cables to the car in an elevator shaft. Typically, they are connected from each tower to its respective end of the lift span in a drooped arrangement. The cables then run along the length of the span to connect the two sets of drooped cables, thereby providing electrical continuity from between the two towers as well as to the lift span.

Advantages of Droop Cables include:

- Droop cables are the only viable option to get adequate power to the bridge operating machinery on the lift span for span drive bridges
- Other lift span electrical components such as navigation lights and roadway lights require no additional type of cable system

Disadvantages of Droop Cables include:

- The cables are continuously flexed during each operation of the bridge and must be special extra flexible cables for acceptable service life
- The droop cables are visible and may be determined to negatively affect bridge aesthetics
- Droop cables can be blown against the tower structures during bridge operations, making them vulnerable to snagging and damage
- Droop cables require the most maintenance since they are always moving/flexing during bridge operations

For aesthetic considerations, the submarine cables would be most advantageous for tower drive systems, but are not suitable for the needed electrical connectivity to the lift span. Therefore, the droop cable system is recommended for span drive systems. Droop cables can often be partially hidden within the towers to minimize the aesthetic impact.

C.4 Summary of Vertical Lift Span Alternatives

The summary of vertical lift span alternatives types that will be considered for this study are as follows:

- Alternative E – Vertical Lift Girder Span with Concrete Frame Towers
- Alternative F – Vertical Lift Girder Span with Steel Frame Towers
- Alternative G – Vertical Lift Truss Span with Trussed Towers

D. Swing Span Alternatives

Another option for the Broadway Bridge would be to use a swing span structure. A swing span rotates on a center pivot pier, allowing navigational traffic to pass the bridge. Because high and low profiles are available, both through and deck swing span structures area feasible options. For the higher profile, a deck girder superstructure could be used, and for the lower profile, a through truss superstructure could be used.

D.1 Swing Span Configurations

A traditional swing span has two sides of equal length. For a traditional swing span to span the entire 170'-0" navigational channel required for Alignment A and B, the total bridge length would be required to be approximately 472 ft (492 ft for Alignment C and 612 ft for Alignment D). This will result in a larger span length than other movable bridge types. Building a swing span of this length will have a construction cost greater than other movable bridge types at this location. Traditional single swing span bridges can be constructed with a through girder or truss superstructure (Figure 19) or deck girder or truss superstructure (Figure 20). Conceptual sketches of traditional swing span options, with either a deck girder superstructure or a through truss superstructure, can be found in Appendix A as Alternates H-2 and I-2.

A bobtail swing bridge, where the two sides of the swing span are of unequal length, could be considered as an alternative to a traditional single swing span bridge. This would allow the side of the swing span that is not located over the navigational channel to be made shorter, thereby shortening the total length of the movable structure. The shorter leaf of the bobtail swing would be counterweighted to balance the weight of the longer leaf. The required span length for the bobtail swing alternative at this location would be 354 ft. for Alignment A or B (369 ft. for Alignment C and 459 ft. for Alignment D). An example of a bobtail swing bridge is included as Figure 21. Conceptual sketches of bobtail swing span options, with either a deck girder superstructure or a through truss superstructure, can be found in Appendix A as Alternates H-1 or I-1.

Figure 19 – I Street Bridge, Sacramento, CA

Figure 20 – Little Potato Slough Bridge, Terminous, CA

Figure 21 – St. Peters Canal Bridge, St. Peters, Nova Scotia

D.2 Mechanical and Electrical System

Swing span machinery consists of a track around a central pivot bearing located on the center pier. Power to rotate the span is provided by two electric motors located symmetrically across the center bearing from each other. Each motor is mechanically connected to right angle gear reducer which are in turn connected to pinions that run along the stationary track surrounding the center bearing. Hydraulically operated swing spans are also an option.

Control System

The choice of between a PLC or relay based control system for a swing bridge is similar to the bascule bridge. For the same reasons as the bascule alternatives, a PLC system is recommended for all swing bridge alternatives.

Cross Channel Cable System

Electrical connectivity is required between the operator's house, center pier, and approach on the opposite side of the channel from the operator's house. There are two viable alternatives to achieve this connectivity for the major power and control needs. Aerial cables and submarine cables are generally the same as for the bascule alternatives. Aerial cables on swing bridges would attach to the moving span above the central pivot point to minimize the flexing of the cables. A cable guide system would be required for connection from the submarine cable to the movable span to account for the rotation of the span. Similar to the bascule alternatives, the additional cost of the submarine cables should be balanced by the aesthetic impact to the bridge. Submarine cables are recommended for all swing bridge alternatives as they provide a longer service life, lower maintenance cost, and are more aesthetically pleasing.

D.3 Summary of Swing Span Alternatives

The summary of swing span alternatives types that will be considered for this study are as follows:

- Alternative H-1 – Bobtail Swing Through Truss Spans
- Alternative H-2 – Swing Through Truss Spans
- Alternative I-1 – Bobtail Swing Deck Girder Spans
- Alternative I-2 – Swing Deck Girder Spans

E. Summary of Movable Bridge Alternatives

The summary of movable bridge alternatives that will be considered for this study are as follows:

- Alternative A – Fully Counterweighted Two Leaf Deck Bascule Girder
- Alternative B – Partially Counterweighted Two Leaf Deck Bascule Girder
- Alternative C – Fully Counterweighted Two Leaf Rolling Bascule Truss
- Alternative D – Partially Counterweighted Two Leaf Rolling Bascule Truss
- Alternative E – Vertical Lift Girder Span with Concrete Frame Towers
- Alternative F – Vertical Lift Girder Span with Steel Frame Towers
- Alternative G – Vertical Lift Truss Span with Trussed Towers
- Alternative H-1 – Bobtail Swing Through Truss Spans
- Alternative H-2 – Swing Through Truss Spans
- Alternative I-1 – Bobtail Swing Deck Girder Spans
- Alternative I-2 – Swing Deck Girder Spans

V. Cost Comparison

The conceptual level construction cost has been developed for each viable bridge type considered. The construction cost as calculated for this report include the following:

- Construction Costs (concrete, steel, etc.)
- Contingency
- Mobilization
- Aesthetic Enhancements

All construction costs are calculated using 2018 unit costs.

The contingency is the increase in the construction cost to account uncertainties due to the level of design that has been completed for this report. The contingency included in this study was 25%. The cost of mobilization was included as 5% of the construction costs.

It is anticipated that this structure will become a signature structure for the cities of West Sacramento and Sacramento. Aesthetics will be a large component of the final design. Because of the importance of the structure, an additional $25 million was included for aesthetic treatments.

All values are reported in millions of dollars.

Bridge Alt.	Description	Movable Span Length	Structure Width	Construction Cost	Contingency and Mobilization	Aesthetics	Total
A	Fully Counterweighted Two Leaf Deck Bascule Girder	230'-0"	83'-0"	$53.1	$15.9	$25	$94.0
B	Partially Counterweighted Two Leaf Deck Bascule Girder	230'-0"	83'-0"	$50.3	$15.1	$25	$90.4
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	258'-6"	90'-6"	$52.5	$15.8	$25	$93.3
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	258'-6"	90'-6"	$51.0	$15.3	$25	$91.3
E	Vertical Lift Girder Span with Concrete Frame Towers	199'-0"	95'-6"	$48.3	$14.5	$25	$87.8
F	Vertical Lift Girder Span with Steel Frame Towers	199'-0"	95'-6"	$44.5	$13.4	$25	$82.9
G	Vertical Lift Truss Span with Trussed Towers	199'-0"	90'-6"	$47.7	$14.3	$25	$87.0
H-1	Bobtail Swing Through Truss Spans	354'-0"	90'-6"	$48.6	$14.6	$25	$88.2
H-2	Swing Through Truss Spans	472'-0"	90'-6"	$53.0	$15.9	$25	$93.9
I-1	Bobtail Swing Deck Girder Spans	354'-0"	83'-0"	$48.4	$14.5	$25	$87.9
I-2	Swing Deck Girder Spans	472'-0"	83'-0"	$52.8	$15.8	$25	$93.6

Table 3 – Construction Cost Estimates – Alignments A and B

Bridge Alt.	Description	Movable Span Length	Structure Width	Construction Cost	Contingency and Mobilization	Aesthetics	Total
A	Fully Counterweighted Two Leaf Deck Bascule Girder	240'-0"	83'-0"	$57.8	$17.3	$25	$100.1
B	Partially Counterweighted Two Leaf Deck Bascule Girder	240'-0"	83'-0"	$54.8	$16.4	$25	$96.2
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	271'-0"	90'-6"	$57.7	$17.3	$25	$100.0
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	271'-0"	90'-6"	$56.1	$16.8	$25	$97.9
E	Vertical Lift Girder Span with Concrete Frame Towers	209'-0"	95'-6"	$50.7	$15.2	$25	$90.9
F	Vertical Lift Girder Span with Steel Frame Towers	209'-0"	95'-6"	$46.7	$14.0	$25	$85.7
G	Vertical Lift Truss Span with Trussed Towers	209'-0"	90'-6"	$50.1	$15.0	$25	$90.1
H-1	Bobtail Swing Through Truss Spans	369'-0"	90'-6"	$52.8	$15.8	$25	$93.6
H-2	Swing Through Truss Spans	492'-0"	90'-6"	$57.6	$17.3	$25	$99.9
I-1	Bobtail Swing Deck Girder Spans	369'-0"	83'-0"	$52.6	$15.8	$25	$93.4
I-2	Swing Deck Girder Spans	492'-0"	83'-0"	$57.4	$17.2	$25	$99.6

Table 4 – Construction Cost Estimates – Alignment C

Bridge Alt.	Description	Movable Span Length	Structure Width	Construction Cost	Contingency and Mobilization	Aesthetics	Total
A	Fully Counterweighted Two Leaf Deck Bascule Girder	300'-0"	83'-0"	Costs not determined. Span length is exceptionally long for bridge type.			
B	Partially Counterweighted Two Leaf Deck Bascule Girder	300'-0"	83'-0"	Costs not determined. Span length is exceptionally long for bridge type			
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	323'-6"	90'-6"	$82.2	$24.7	$25	$131.9
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	323'-6"	90'-6"	$79.9	$24	$25	$128.9
E	Vertical Lift Girder Span with Concrete Frame Towers	269'-0"	95'-6"	$65.3	$19.6	$25	$109.9
F	Vertical Lift Girder Span with Steel Frame Towers	269'-0"	95'-6"	$60.2	$18.1	$25	$103.3
G	Vertical Lift Truss Span with Trussed Towers	269'-0"	90'-6"	$64.5	$19.4	$25	$108.9
H-1	Bobtail Swing Through Truss Spans	459'-0"	90'-6"	$81.7	$24.5	$25	$131.2
H-2	Swing Through Truss Spans	612'-0"	90'-6"	$89.1	$26.7	$25	$140.8
I-1	Bobtail Swing Deck Girder Spans	459'-0"	83'-0"	Costs not determined. Span length is exceptionally long for bridge type.			
I-2	Swing Deck Girder Spans	612'-0"	83'-0"	Costs not determined. Span length is exceptionally long for bridge type.			

Table 5 – Construction Cost Estimates – Alignment D

VI. Bridge Type Evaluation Matrix

The evaluation matrix was created to assist in rating the bridge types, according to the project goals discussed in earlier sections of this report and ultimately choosing the movable bridge type for the new Broadway Bridge. Each bridge type in the evaluation matrix was scored according to the evaluation criteria. The score that was assigned to the bridge type for each of the evaluation criteria was determined in a process described below.

A. Evaluation Criteria

The bridge alternatives were assessed both qualitatively and quantitatively using three primary evaluation categories: Performance, Construction Cost, and Life Cycle Costs. A description of the three evaluation categories, and the criteria considered in each, follow.

Performance

- Constructability and Construction Schedule
    - Complexity of anticipated construction methods
    - Extent of work in the river
    - Estimated duration of construction
    - Level of safety during construction
- Environmental and Site Impacts
    - Effect of construction on river navigation
    - Extent of temporary access or staging areas
    - Permanent impacts of the substructure units on the site (hydraulic concerns, etc.)
- Mobility and Connectivity
    - Ability to provide access for vehicles, pedestrians, and bicyclists
    - Ability to meet all applicable ADA requirements
    - Ability to provide connection to existing streets
- Future Streetcar
    - Complexity of adding streetcar access to structure in the future

Construction Costs

- Construction costs and contingencies as described in the previous section

Life Cycle Costs

- Inspection
    - Complexity of routine and in-depth inspections
    - Accessibility of components requiring inspection
    - Estimated duration of inspections
    - Need for traffic control during inspections
    - Need for complex structural analysis to determine future, as-inspected ratings
- Maintenance
    - Complexity of routine maintenance
    - Quantity and types of bridge components to maintain
    - Accessibility of components requiring maintenance
- Long Term Maintenance and Rehabilitation
    - Frequency and costs of anticipated long term maintenance effort
    - Frequency and cost of anticipated long term rehabilitation effort

B. Evaluation Matrix

An Evaluation Matrix was developed to quantitatively compare the bridge types and to assist in identifying the preferred alternative. For each of the four evaluation categories previously defined, the bridge alternatives were numerically rated according to the characteristics of, or performance provided by, the alternative. The following scale of 1 to 4 was used for the ratings:

1 Poor
2 Fair
3 Good
4 Excellent

The complete Evaluation Matrix is included as Appendix B.

B.1 Performance:

Within the performance category, the bridge alternatives were rated for each of the four contributing criteria (Constructability and Construction Schedule, Environmental and Site Impacts, Mobility and Connectivity, and Future Streetcar). Each of the four performance criteria was assigned a weight according to its relative level of importance in comparison to the remaining criteria. Weights, relating to the subjective importance of each criterion, were assigned to each item. The weights are shown below:

Performance Criterion	Weight
Constructability and Construction Schedule	40
Environmental and Site Impacts	40
Mobility and Connectivity	10
Future Streetcar	10

After each bridge alternative was rated for each of the performance criteria, an average weighted total performance rating was calculated for each alternative. These average weighted ratings provide the quantitative measure of performance provided by each bridge type.

Constructability and Construction Schedule Rating				
Alternative		Positives	Negatives	Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	• Girder fabrication and erection is typically easier than truss work • Portions of bascule span could be floated in place, limiting impacts to navigation during construction • Lightest structure for float-in	• Two large box piers require cofferdam and increased river work • Requires partial closure of navigation channel during portions of construction • Span length/width is large for this type of bridge, requiring risks during construction	2
B	Partially Counterweighted Two Leaf Deck Bascule Girder	• Girder fabrication and erection is typically easier than truss work • Portions of bascule span could be floated in place, limiting impacts to navigation during construction • Lightest structure for float-in • Decreases construction effort for counterweight • Hydraulic system is simpler to align and allows more work to be completed in controlled shop environment	• Two large box piers require cofferdam and increased river work • Requires partial closure of navigation channel during portions of construction • Span length/width is large for this type of bridge, requiring risks during construction	2
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	• Portions of bascule span could be floated in place, limiting impacts to navigation during construction • Lightest structure for float-in	• Span length/width is large for this type of bridge, requiring risks during construction • Requires partial closure of navigation channel during portions of construction • Truss connections can increase time and complexity for construction	3
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	• Portions of bascule span could be floated in place, limiting impacts to navigation during construction • Lightest structure for float-in • Decreases construction effort for counterweight • Hydraulic system is simpler to align and allows more work to be completed in controlled shop environment	• Span length/width is large for this type of bridge, requiring risks during construction • Requires partial closure of navigation channel during portions of construction • Truss connections can increase time and complexity for construction	4
E	Vertical Lift Girder Span with Concrete Frame Towers	• Girder fabrication and erection is typically easier than truss work • Concrete Towers provide flexibility with precast and cast-in-place options	• Construction of towers requires increased time for construction in the river	3

		• Within range of typical vertical lift span length • Lift span could be floated in place, limiting impacts to river navigation during construction		
F	Vertical Lift Girder Span with Steel Frame Towers	• Girder fabrication and erection is typically easier than truss work • Within range of typical vertical lift span length • Lift span could be floated in place, limiting impacts to river navigation during construction	• Construction of towers requires increased time for construction in the river	3
G	Vertical Lift Truss Span with Trussed Towers	• Within range of typical vertical lift span length • Lift span could be floated in place, limiting impacts to river navigation during construction	• Construction of towers requires increased time for construction in the river • Multiple truss connections can increase time and complexity for construction	3
H-1	Bobtail Swing Through Truss Spans	• Swing span could be erected in open position, avoiding closure of navigational channel	• Span length is large for a swing span, requiring risks during construction • Truss connections can increase time and complexity for construction	3
H-2	Swing Through Truss Spans	• Swing span could be erected in open position, avoiding closure of navigational channel	• Span length is large for a swing span, requiring risks during construction • Truss connections can increase time and complexity for construction	3
I-1	Bobtail Swing Deck Girder Spans	• Girder fabrication and erection is typically easier than truss work • Swing span could be erected in open position, avoiding closure of navigational channel	• Span length is large for a swing span, requiring risks during construction	4
I-2	Swing Deck Girder Spans	• Girder fabrication and erection is typically easier than truss work • Swing span could be erected in open position, avoiding closure of navigational channel	• Span length is large for a swing span, requiring risks during construction	4

Table 6 – Performance Rating – Constructability and Construction Schedule

Environmental and Site Impacts Rating				
Alternative		Positives	Negatives	Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder		• Greatest hydraulic impact due to two large box piers	2
B	Partially Counterweighted Two Leaf Deck Bascule Girder		• Greatest hydraulic impact due to two large box piers	2
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	• Lowest hydraulic impact due to smaller bascule pier footprints		4
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	• Lowest hydraulic impact due to smaller bascule pier footprints		4
E	Vertical Lift Girder Span with Concrete Frame Towers	• Lowest hydraulic impact due to smaller tower footprints		4
F	Vertical Lift Girder Span with Steel Frame Towers	• Lowest hydraulic impact due to smaller tower footprints		4
G	Vertical Lift Truss Span with Trussed Towers	• Lowest hydraulic impact due to smaller tower footprints		4
H-1	Bobtail Swing Through Truss Spans	• Pivot pier supported on drilled shafts will limit effect on river hydraulics	• Large environmental footprint for swing span fender system	1
H-2	Swing Through Truss Spans	• Pivot pier supported on drilled shafts will limit effect on river hydraulics	• Large environmental footprint for swing span fender system	1
I-1	Bobtail Swing Deck Girder Spans	• Pivot pier supported on drilled shafts will limit effect on river hydraulics	• Large environmental footprint for swing span fender system	1
I-2	Swing Deck Girder Spans	• Pivot pier supported on drilled shafts will limit effect on river hydraulics	• Large environmental footprint for swing span fender system	1

Table 7 – Performance Rating - Environmental and Site Impacts

Mobility and Connectivity Rating				
Alternative		Positives	Negatives	Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	• Deck girder could meet all mobility and connectivity requirements	• Deck girder would only be possible with higher profile grade	3
B	Partially Counterweighted Two Leaf Deck Bascule Girder	• Deck girder could meet all mobility and connectivity requirements • Hydraulic bascule would have the shortest opening time	• Deck girder would only be possible with higher profile grade	4
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	• Through truss could meet all mobility and connectivity requirements		4
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	• Through truss could meet all mobility and connectivity requirements • Hydraulic bascule span would have the shortest opening time		4
E	Vertical Lift Girder Span with Concrete Frame Towers	• Through girder could meet all mobility and connectivity requirements		4
F	Vertical Lift Girder Span with Steel Frame Towers	• Through girder could meet all mobility and connectivity requirements		4
G	Vertical Lift Truss Span with Trussed Towers	• Through truss could meet all mobility and connectivity requirements		4
H-1	Bobtail Swing Through Truss Spans	• Through truss could meet all mobility and connectivity requirements	• Swing span would have the longest opening time	3
H-2	Swing Through Truss Spans	• Through truss could meet all mobility and connectivity requirements	• Swing span would have the longest opening time	3
I-1	Bobtail Swing Deck Girder Spans	• Deck girder could meet all mobility and connectivity requirements	• Deck girder would only be possible with higher profile grade • Swing span would have the longest opening time	3
I-2	Swing Deck Girder Spans	• Deck girder could meet all mobility and connectivity requirements	• Deck girder would only be possible with higher profile grade • Swing span would have the longest opening time	3

Table 8 – Performance Rating - Mobility and Connectivity

Future Streetcar Rating				
Alternative		Positives	Negatives	Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder		• More adjustments needed to the counterweight to accommodate future weight • Bascule bridge type would require the most miter rails which are maintenance prone	3
B	Partially Counterweighted Two Leaf Deck Bascule Girder	• Hydraulic bascule requires fewer adjustments to the counterweight to accommodate future weight	• Bascule bridge type would require the most miter rails which are maintenance prone	3
C	Fully Counterweighted Two Leaf Rolling Bascule Truss		• More adjustments needed to the counterweight to accommodate future weight • Bascule bridge type would require the most miter rails which are maintenance prone • An overhead truss structure would need to provide enough vertical clearance for possible streetcar configurations	3
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	• Hydraulic bascule requires fewer adjustments to the counterweight to accommodate future weight	• Bascule bridge type would require the most miter rails which are maintenance prone • An overhead truss structure would need to provide enough vertical clearance for possible streetcar configurations	3
E	Vertical Lift Girder Span with Concrete Frame Towers	• Vertical lift spans are historically well suited for rail loadings		4
F	Vertical Lift Girder Span with Steel Frame Towers	• Vertical lift spans are historically well suited for rail loadings		4
G	Vertical Lift Truss Span with Trussed Towers	• Vertical lift spans are historically well suited for rail loadings	• An overhead truss structure would need to provide enough vertical clearance for possible streetcar configurations	4
H-1	Bobtail Swing Through Truss Spans		• An overhead truss structure would need to provide enough vertical clearance for possible streetcar configurations • Miter rails on swing bridges are historically problematic and require more maintenance	3

H-2	Swing Through Truss Spans		• An overhead truss structure would need to provide enough vertical clearance for possible streetcar configurations • Miter rails on swing bridges are historically problematic and require increased maintenance	3
I-1	Bobtail Swing Deck Girder Spans		• Miter rails on swing bridges are historically problematic and require increased maintenance	3
I-2	Swing Deck Girder Spans		• Miter rails on swing bridges are historically problematic and require increased maintenance	3

Table 9 – Performance Rating - Future Streetcar

B.2 Construction Costs:

The construction costs of each alternative were rated using a scale of 1 to 4. The average bridge alternative construction costs were assigned a rating of 3. Other alternatives were scored based on their percent difference relative to the average cost alternative with an assigned slope factor to achieve a rating of 4 for the lowest cost alternative. Construction cost ratings have been determined for Alignments A/B, C, and D. The bridge types have been rated as follows:

Alternative		Construction Cost Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	2.4
B	Partially Counterweighted Two Leaf Deck Bascule Girder	2.9
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	2.5
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	2.8
E	Vertical Lift Girder Span with Concrete Frame Towers	3.3
F	Vertical Lift Girder Span with Steel Frame Towers	4.0
G	Vertical Lift Truss Span with Trussed Towers	3.4
H-1	Bobtail Swing Through Truss Spans	3.3
H-2	Swing Through Truss Spans	2.5
I-1	Bobtail Swing Deck Girder Spans	3.3
I-2	Swing Deck Girder Spans	2.5

Table 10 – Construction Cost Ratings – Alignments A/B

Alternative		Construction Cost Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	2.5
B	Partially Counterweighted Two Leaf Deck Bascule Girder	2.9
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	2.5
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	2.7
E	Vertical Lift Girder Span with Concrete Frame Towers	3.5
F	Vertical Lift Girder Span with Steel Frame Towers	4.0
G	Vertical Lift Truss Span with Trussed Towers	3.5
H-1	Bobtail Swing Through Truss Spans	3.2
H-2	Swing Through Truss Spans	2.5
I-1	Bobtail Swing Deck Girder Spans	3.2
I-2	Swing Deck Girder Spans	2.5

Table 11 – Construction Cost Ratings – Alignment C

Alternative		Construction Cost Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	-
B	Partially Counterweighted Two Leaf Deck Bascule Girder	-
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	2.5
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	2.6
E	Vertical Lift Girder Span with Concrete Frame Towers	3.6
F	Vertical Lift Girder Span with Steel Frame Towers	4.0
G	Vertical Lift Truss Span with Trussed Towers	3.7
H-1	Bobtail Swing Through Truss Spans	2.5
H-2	Swing Through Truss Spans	2.0
I-1	Bobtail Swing Deck Girder Spans	-
I-2	Swing Deck Girder Spans	-

Table 12 – Construction Cost Ratings – Alignments D

B.3 Life Cycle Costs:

Each structure was rated for Life Cycle Costs using the guidelines as previously presented. The structures were rated for each rating criterion, and a total Life Cycle Costs rating was calculated assuming each rating item carried an equal weight.

Inspection Rating				
Alternative		Positives	Negatives	Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	• Access will be provided for inspection of girders		4
B	Partially Counterweighted Two Leaf Deck Bascule Girder	• Access will be provided for inspection of girders	.	4
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	• Access will be provided for inspection of truss and rack frame	• Superstructure truss members and joints require hands on inspection	3
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	• Access will be provided for inspection of truss	• Superstructure truss members and joints require hands on inspection	3
E	Vertical Lift Girder Span with Concrete Frame Towers	• Access will be provided for inspection of girders and towers	• Tower may be difficult to inspect	3
F	Vertical Lift Girder Span with Steel Frame Towers	• Access will be provided for inspection of girders and towers	• Tower members may be difficult to inspect	2
G	Vertical Lift Truss Span with Trussed Towers	• Access will be provided for inspection of truss and towers	• Tower members may be difficult to inspect • Superstructure truss members and joints require hands on inspection. • Connections on steel trussed towers require hands on inspection every inspection cycle	2
H-1	Bobtail Swing Through Truss Spans	• Access will be provided for inspection of machinery at pivot pier and rest piers	• Superstructure truss members and joints require hands on inspection	3
H-2	Swing Through Truss Spans	• Access will be provided for inspection of machinery at pivot pier and rest piers	• Superstructure truss members and joints require hands on inspection • Structure length is significantly longer than other options, increasing inspection effort	2
I-1	Bobtail Swing Deck Girder Spans	• Access will be provided for inspection of machinery at pivot pier and rest piers		4
I-2	Swing Deck Girder Spans	• Access will be provided for inspection of machinery at pivot pier and rest piers	• Structure length is significantly longer than other options, increasing inspection effort	3

Table 13 – Life Cycle Costs –Inspection Ratings

Maintenance Rating				
Alternative		Positives	Negatives	Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	• Most machinery is easily accessible and protected from the environment		3
B	Partially Counterweighted Two Leaf Deck Bascule Girder	• Most machinery is easily accessible and protected from the environment • Lower O&M cost and effort for hydraulic drive system		4
C	Fully Counterweighted Two Leaf Rolling Bascule Truss	• Most machinery is easily accessible and protected	• Monitoring of alignment and wear of segment girder and track girder required	3
D	Partially Counterweighted Two Leaf Rolling Bascule Truss	• Most machinery is easily accessible and protected • Lower O&M cost and effort for hydraulic drive system	• Monitoring of alignment and wear of segment girder and track girder required	4
E	Vertical Lift Girder Span with Concrete Frame Towers	• Most machinery is protected	• Accessing machinery on tower tops requires more effort than other bridge types	2
F	Vertical Lift Girder Span with Steel Frame Towers	• Most machinery is easily accessible and protected	• Accessing machinery on tower tops requires more effort than other bridge types	2
G	Vertical Lift Truss Span with Trussed Towers	• Most machinery is easily accessible and protected	• Accessing machinery on tower tops or span requires more effort than other bridge types	2
H-1	Bobtail Swing Through Truss Spans	• Maintenance effort mainly occurs at one location (pivot pier)	• Machinery may be less accessible than other alternatives	2
H-2	Swing Through Truss Spans	• Maintenance effort mainly occurs at one location (pivot pier)	• Machinery may be less accessible than other alternatives	2
I-1	Bobtail Swing Deck Girder Spans	• Maintenance effort mainly occurs at one location (pivot pier)	• Machinery may be less accessible than other alternatives	2
I-2	Swing Deck Girder Spans	• Maintenance effort mainly occurs at one location (pivot pier)	• Machinery may be less accessible than other alternatives	2

Table 14 – Life Cycle Costs –Maintenance Ratings

Long Term Maintenance and Rehabilitation Rating				
Alternative		Positives	Negatives	Rating
A	Fully Counterweighted Two Leaf Deck Bascule Girder	• Deck girder repainting effort will be less than truss alternatives • Repainting could occur with minimal effect on vehicular traffic	• Superstructure will require repainting during the life of the structure	4
B	Partially Counterweighted Two Leaf Deck Bascule Girder	• Deck girder repainting effort will be less than truss alternatives • Repainting could occur with minimal effect on vehicle traffic	• Superstructure will require repainting during the life of the structure	4
C	Fully Counterweighted Two Leaf Rolling Bascule Truss		• Monitoring of alignment and wear of segment girder and track girder required • Superstructure will require repainting during the life of the structure • Truss superstructure repainting effort will be greater than girder alternatives	3
D	Partially Counterweighted Two Leaf Rolling Bascule Truss		• Monitoring of alignment and wear of segment girder and track girder required • Superstructure will require repainting during the life of the structure • Truss superstructure repainting effort will be greater than girder alternatives	3
E	Vertical Lift Girder Span with Concrete Frame Towers	• Concrete towers have low maintenance costs and require no future painting • Girder repainting effort will be less than truss alternatives	• Operating/counterweight ropes will need to be replaced during the life of the bridge • Maintenance of the ropes can be difficult, time consuming, and costly • Superstructure will require repainting during the life of the structure	3
F	Vertical Lift Girder Span with Steel Frame Towers	• Girder and tower repainting effort will be less than truss alternatives	• Operating/counterweight ropes will need to be replaced during the life of the bridge • Maintenance of the ropes can be difficult, time consuming, and costly • Superstructure will require repainting during the life of the structure	2

			• Steel frame towers require repainting during the life of the structure	
G	Vertical Lift Truss Span with Trussed Towers		• Operating/counterweight ropes will need to be replaced during the life of the bridge • Maintenance of the ropes can be difficult, time consuming, and costly • Superstructure will require repainting during the life of the structure • Steel trussed towers require repainting during the life of the structure • Truss superstructure and tower repainting effort will be greater than girder alternatives	2
H-1	Bobtail Swing Through Truss Spans		• Superstructure will require repainting during the life of the structure • Truss superstructure repainting effort will be greater than girder alternatives	3
H-2	Swing Through Truss Spans		• Structure length is significantly longer than other alternatives, increasing maintenance and rehabilitation effort • Superstructure will require repainting during the life of the structure • Truss superstructure repainting effort will be greater than girder alternatives	2
I-1	Bobtail Swing Deck Girder Spans	• Deck girder repainting effort will be less than truss alternatives • Repainting could occur with minimal effect on vehicle traffic	• Superstructure will require repainting during the life of the structure	4
I-2	Swing Deck Girder Spans	• Deck girder repainting effort will be less than truss alternatives • Repainting could occur with minimal effect on vehicle traffic	• Structure length is significantly longer than other alternatives, increasing maintenance and rehabilitation effort • Superstructure will require repainting during the life of the structure	3

Table 15 – Life Cycle Costs – Long Term Maintenance and Rehabilitation Ratings

The complete Evaluation Matrix, with ratings for each of the bridge alternatives, is provided in Appendix B.

C. Weighting Factors

To determine a final rating for each bridge alternative incorporating the three evaluation categories, weights were assigned to the evaluation categories according to their relative level of importance. This enabled calculation of a weighted rating for the alternatives, and subsequently, facilitated ranking the bridge types according to the total ratings.

As a baseline ranking of the bridge types, equal weights were assigned to each of the three primary evaluation categories. Thus, each category was assigned a weight of 33% of the total rating. A sensitivity study was then conducted to determine whether changes to the category weights altered the ranking of bridge alternatives. Three additional cases were investigated, Cases A through C, each assigning a majority weight to one of the three evaluation categories and distributing the remaining weight among the other three categories. Case A assigned a 50% weight to Construction Cost, Case B assigned 50% to Life Cycle Costs, and Case C assigned 50% to Performance. The bridge rankings for each case investigated are shown in the following tables. The highest rated bridge type was ranked as a 1, with the additional bridge types ranked appropriately.

			Bridge Ranking Cases			
			Equal Wt.	A	B	C
Category Weights	Performance		33%	25%	25%	50%
	Construction Cost		33%	50%	25%	25%
	Life Cycle Cost		33%	25%	50%	25%
Alternative	A	Fully Counterweighted Two Leaf Deck Bascule Girder	8	9	6	8
	B	Partially Counterweighted Two Leaf Deck Bascule Girder	5	6	2	7
	C	Fully Counterweighted Two Leaf Rolling Bascule Truss	7	7	5	5
	D	Partially Counterweighted Two Leaf Rolling Bascule Truss	1	3	1	1
	E	Vertical Lift Girder Span with Concrete Frame Towers	3	2	4	3
	F	Vertical Lift Girder Span with Steel Frame Towers	2	1	7	2
	G	Vertical Lift Truss Span with Trussed Towers	6	5	8	4
	H-1	Bobtail Swing Through Truss Spans	9	8	9	9
	H-2	Swing Through Truss Spans	11	11	11	11
	I-1	Bobtail Swing Deck Girder Spans	4	4	3	6
	I-2	Swing Deck Girder Spans	10	10	10	9

Table 16 – Weighting Factors Sensitivity Study – Alignments A/B

			Bridge Ranking Cases			
			Equal Wt.	A	B	C
Category Weights	Performance		33%	25%	25%	50%
	Construction Cost		33%	50%	25%	25%
	Life Cycle Cost		33%	25%	50%	25%
Alternative	A	Fully Counterweighted Two Leaf Deck Bascule Girder	8	9	5	8
	B	Partially Counterweighted Two Leaf Deck Bascule Girder	4	6	2	7
	C	Fully Counterweighted Two Leaf Rolling Bascule Truss	7	7	6	5
	D	Partially Counterweighted Two Leaf Rolling Bascule Truss	1	3	1	1
	E	Vertical Lift Girder Span with Concrete Frame Towers	2	2	4	2
	F	Vertical Lift Girder Span with Steel Frame Towers	3	1	7	3
	G	Vertical Lift Truss Span with Trussed Towers	6	4	8	4
	H-1	Bobtail Swing Through Truss Spans	9	8	9	10
	H-2	Swing Through Truss Spans	11	11	11	11
	I-1	Bobtail Swing Deck Girder Spans	5	5	3	6
	I-2	Swing Deck Girder Spans	10	10	10	9

Table 17 – Weighting Factors Sensitivity Study – Alignment C

			Bridge Ranking Cases			
			Equal Wt.	A	B	C
Category Weights	Performance		33%	25%	25%	50%
	Construction Cost		33%	50%	25%	25%
	Life Cycle Cost		33%	25%	50%	25%
Alternative	A	Fully Counterweighted Two Leaf Deck Bascule Girder	-	-	-	-
	B	Partially Counterweighted Two Leaf Deck Bascule Girder	-	-	-	-
	C	Fully Counterweighted Two Leaf Rolling Bascule Truss	5	5	3	5
	D	Partially Counterweighted Two Leaf Rolling Bascule Truss	2	4	1	1
	E	Vertical Lift Girder Span with Concrete Frame Towers	1	2	2	2
	F	Vertical Lift Girder Span with Steel Frame Towers	3	1	4	3
	G	Vertical Lift Truss Span with Trussed Towers	4	3	5	4
	H-1	Bobtail Swing Through Truss Spans	6	6	6	6
	H-2	Swing Through Truss Spans	7	7	7	7
	I-1	Bobtail Swing Deck Girder Spans	-	-	-	-
	I-2	Swing Deck Girder Spans	-	-	-	-

Table 18 – Weighting Factors Sensitivity Study – Alignment D

For Alignments A, B, and C, the baseline case of equal weights for all evaluation categories indicates that the partially counterweighted, rolling lift bascule bridge (Alternative D) is the top ranked bridge type. The vertical lift girder span with steel frame towers (Alternative F) and the vertical lift girder span with concrete towers (Alternative E) are rated second and third highest, although due to the small difference between the ratings these two bridge types can be considered a statistical tie. For Alignment D, the top ranked bridge type is the vertical lift girder span with concrete towers (Alternative E), with the partially counterweighted, rolling lift bascule bridge (Alternative D) and the vertical lift girder span with steel frame towers (Alternative F) ranking second and third, respectively. Increasing the Construction Cost weight to 50% (Case A) changes the order of the top-ranking bridges, with the vertical lift girder span with steel frame towers (Alternative F) rating highest for all alignments and the vertical lift girder span with concrete towers (Alternative E) rating second. Increasing the Life Cycle Cost weight to 50% (Case B) results in the partially counterweighted rolling lift bascule span (Alternative D) being the top-ranking alternative, with the second and third ranked alternative varying depending on the alignment. Increasing the Performance weight to 50% (Case C) results in the partially counterweighted, rolling bascule span (Alternative D) remains the top rated, with the vertical lift girder span with steel towers (Alternative F) and the vertical lift girder span with concrete towers (Alternative E) rating second and third.

The sensitivity study highlights the fact that under the objectives and constraints identified for the Broadway Bridge, the partially counterweighted bascule spans and the vertical lift girder spans rate well in each of the three evaluation categories. While the order of the ranking of these three bridge alternatives may change, the fact that they are the top ranking alternatives is relatively insensitive to the weights assigned to the evaluation categories. In each case investigated, the vertical lift girder structure span alternatives and the partially counterweighted two leaf rolling bascule span alternatives rank at or near the top of the bridge alternatives.

VII. Aesthetics and User Impression

A. Aesthetic Considerations

Each bridge type alternative has the capacity to become an aesthetic and distinct structure for the stakeholders and bridge users. Additionally, all alternatives meet the requirements to be considered a Neighborhood Friendly crossing. Because each alternative has an equal ability to meet the aesthetic requirements, this category was not explicitly included in the decision matrix.

A summary of possible considerations related to the appearance of the Broadway Bridge are summarized in the below table. In additional phases of design, the overall theme of the structure will be discussed and decided upon. This discussion will involve project stakeholders, the Bridge Architect, and the Bridge Design Engineer. These considerations are included to assist in determining if each alternative meets the not-yet-determined overall look to the project. They are not necessarily to be taken as positive or negative points.

Possible Aesthetic Considerations		
Design Feature	Alternative	Consideration
Girder Superstructure	A, B, E, F, I-1, I-2	• Contemporary girder superstructure
Truss Superstructure	C, D, G, H-1, H-2	• Traditional aesthetics of a through truss span
Trunnion Bascule with Underdeck Counterweight	A, B	• Large box piers may dominate river views
Rolling Bascule with Overhead Counterweight	C, D	• Overhead counterweight may appear bulky
Vertical Lift Spans	E, F, G	• Tall towers may dominate surrounding area • Consistent with bridge types currently on the river
Swing Spans	H-1, H-2, I-1, I-2	• Large center pivot pier may dominate river views • Consistent with bridge types currently on the river
Vertical Lift with Concrete Towers	E	• Multiple aesthetic options for tower
Vertical Lift with Concrete Towers	F	• Contemporary column towers
Vertical Lift with Steel Trussed Towers	G	• Traditional aesthetics of the trussed towers

Table 19 – Possible Aesthetic Considerations for Bridge Alternatives

B. Constructed Movable Bridges

Photos of constructed movable bridges have been included previously in the report at multiple locations. Many of these structures have aesthetic features. Along with those photos, a few additional examples of previously constructed movable bridges with aesthetic features are included below.

Figure 22 – Woodrow Wilson Bridge, Washington, D.C.

Figure 23 – Caland Bridge, Rotterdam, Netherlands

Figure 24 – Albatros Bridge, Lázaro Cárdenas, Mexico

Figure 25 – Rethe Bascule Bridge, Hamburg, Germany (Front Bridge)

Figure 26 – Botlekbrug, Rotterdam, Netherlands

Figure 27 – Lower Hatea Bascule Bridge, Whangarei, New Zealand

Figure 28 – Chelsea Street Bridge, Boston, Massachusetts

Figure 29 – Tower Bridge, Sacramento, California

Figure 30 – 17th Street Causeway Bascule Bridge, Ft. Lauderdale, FL

Figure 31 – Boulevard Bridge, Williebroek, Belgium

VIII. Recommendation

Of the eleven viable alternatives that were considered in the Alternatives Evaluation Matrix, the vertical lift girder spans and the two leaf partially counterweighted bascule spans have the highest rankings. The fully counterweighted bascule spans, the truss vertical lift spans, and the swing spans scored lower in comparison and will therefore no longer be considered for further study.

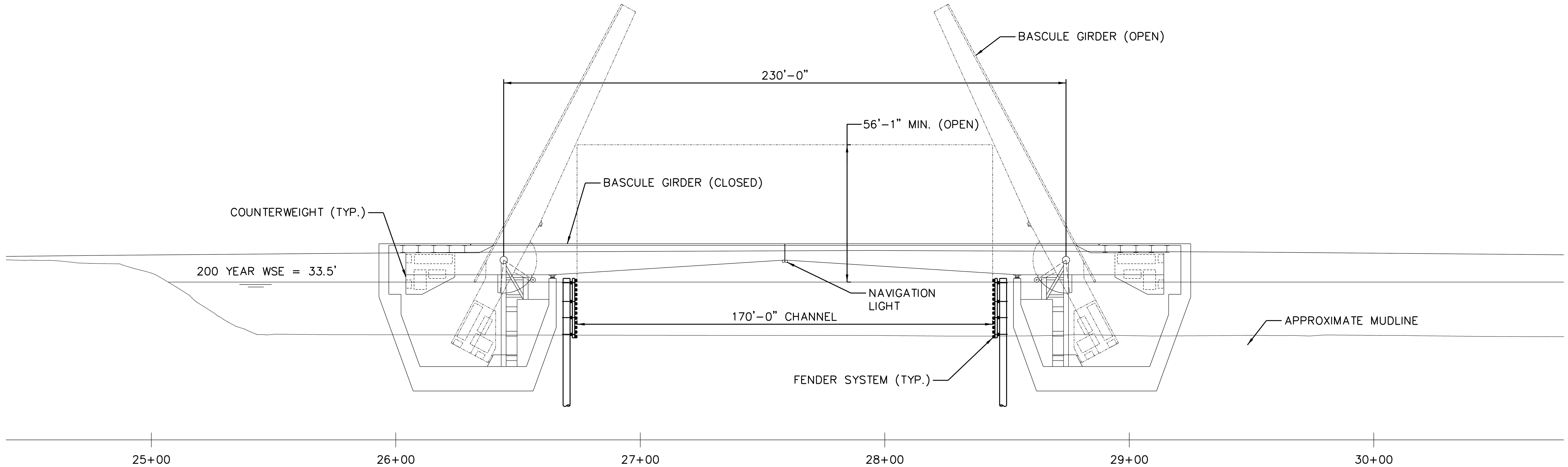
The total score for the partially counterweighted two leaf rolling bascule span (Alternative D) was the highest. The score for the vertical lift girder spans (Alternatives E and F) were only slightly lower. The difference in the scores was close and they may be considered a statistical tie. While each scored higher or lower in individual categories, the final score is too close for either to be considered the distinct winner.

Following are additional qualitative factors to consider.

- The new Broadway Bridge will be a landmark structure between the cities of West Sacramento and Sacramento. This structure will be seen and used by many people and will be an aesthetically pleasing bridge for all. The aesthetic options for the structure will be studied as the design progresses by the stakeholders, the public, and the bridge engineers and architects. At the current time, aesthetics has not been explicitly included in the design of the structures. Carrying forward multiple structure options into the next design phase will allow a wide range of possible options for the aesthetic ideas for the project. The multiple viable bridge types will allow a wider range of aesthetic options to be considered.
- There are four proposed alignments for the new Broadway Bridge. Each alignment crosses the river at a different location which requires the use of different span lengths. The two leaf rolling bascule span as well as the girder vertical lift spans are well suited for the span lengths required for Alignments A, B, and C. The span length required for Alignment D is significantly longer than the other alignments and for this alignment, the vertical lift spans alternates are more highly rated. While the rolling bascule truss alternative still ranks highly for Alignment D, it is traditionally large for a two leaf bascule span. Therefore, the determination of the final alignment will influence the preferred movable bridge alternative.
- The recommended bridge alternatives allow for the use of different vertical alignments. The vertical lift girder spans require the use of the higher vertical alignment. The partially counterweighted rolling bascule span can be used with both the lower and the higher vertical alignment. Both vertical alignments are currently viable for the Broadway Bridge. Again, if it is determined that one vertical alignment is preferred over the other, this will influence the preferred movable bridge alternative.
- Traditionally, rolling bascule bridges require less maintenance effort than vertical lift bridges. This has been accounted for in the decision matrix and was one reason for the rolling bascule's high rating. Although not accounted for in the matrix is the previous experience the local maintenance team may have with vertical lift bridges. The other movable bridges crossing the Sacramento River are vertical lift bridges, including the Tower Bridge and the future I Street Bridge (not yet constructed). The local maintenance team may have experience working with vertical lift bridges which was not explicitly included in the matrix. This experience may influence which bridge type is the preferred alternative.
- The decision matrix as included in this report included performance concerns, long term costs, and initial construction costs. As shown in the Weighting Factor Sensitivity Study, the degree of importance placed on each factor increased the ranking of the bridge alternatives. The final weightings should be determined with the applicable stakeholders. This final weighting will affect the preferred alternative. For example, if the budget concerns require considering initial construction costs to a much higher degree than the other concerns, than the low cost alternative may become more suitable, which would be the girder vertical lift alternative.

Based on these observations, it is recommended that the partially counterweighted two leaf rolling bascule and the vertical lift girder bridge with either steel or concrete towers continue to be advanced until additional project decisions are made. It will be advantageous for the aesthetic considerations for the bridge if these three bridge alternatives remain as viable structure types. This will allow the stakeholders, the public, and the bridge architect more options for creating a signature span. Also, the preferred structure type may vary while additional project decisions are made including determining the final alignment. Continuing developments and additional deciding factors for the Broadway Bridge Project may influence the decision on the preferred bridge type.

Appendix A – Bridge Drawings



ELEVATION

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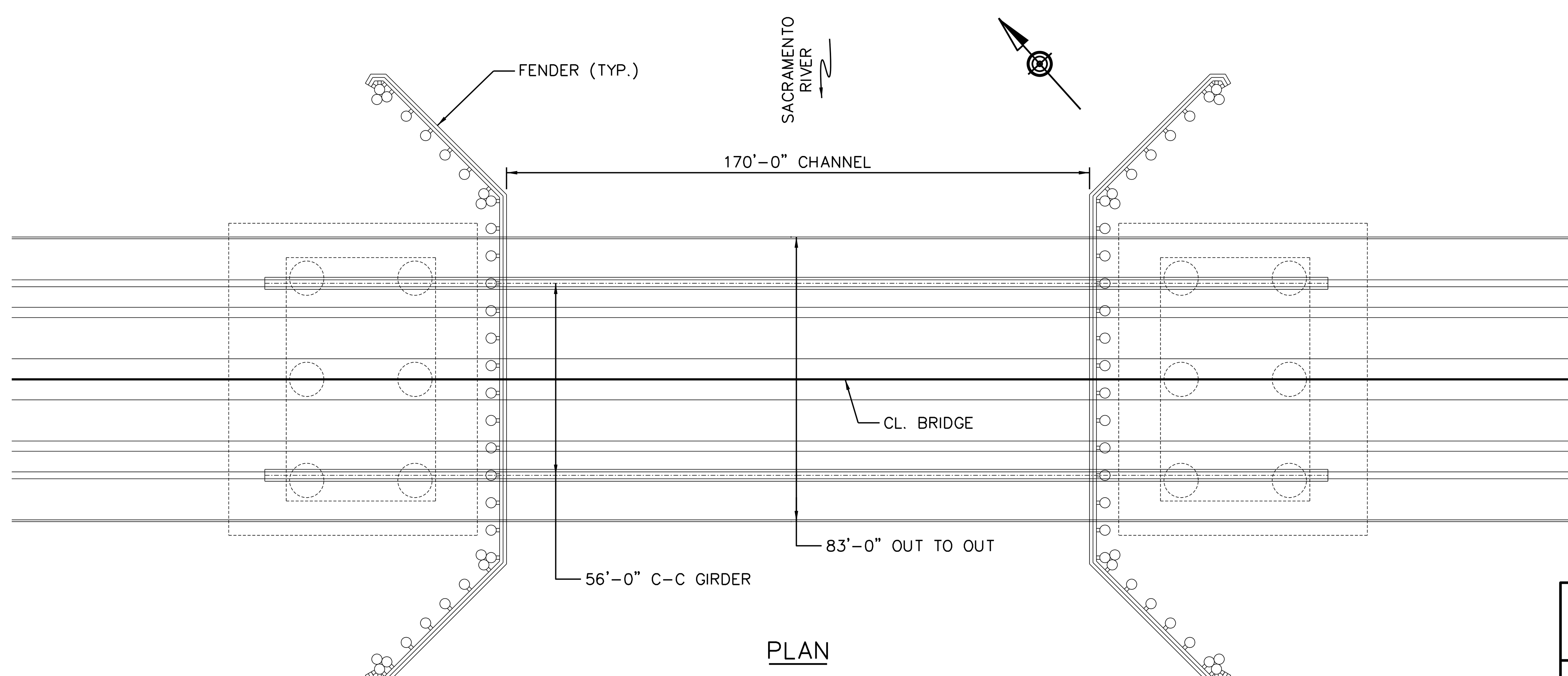

PLAN

20 0 20 40
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE A
FULLY COUNTERWEIGHTED
BASCULE GIRDER SPAN
GENERAL PLAN AND ELEVATION

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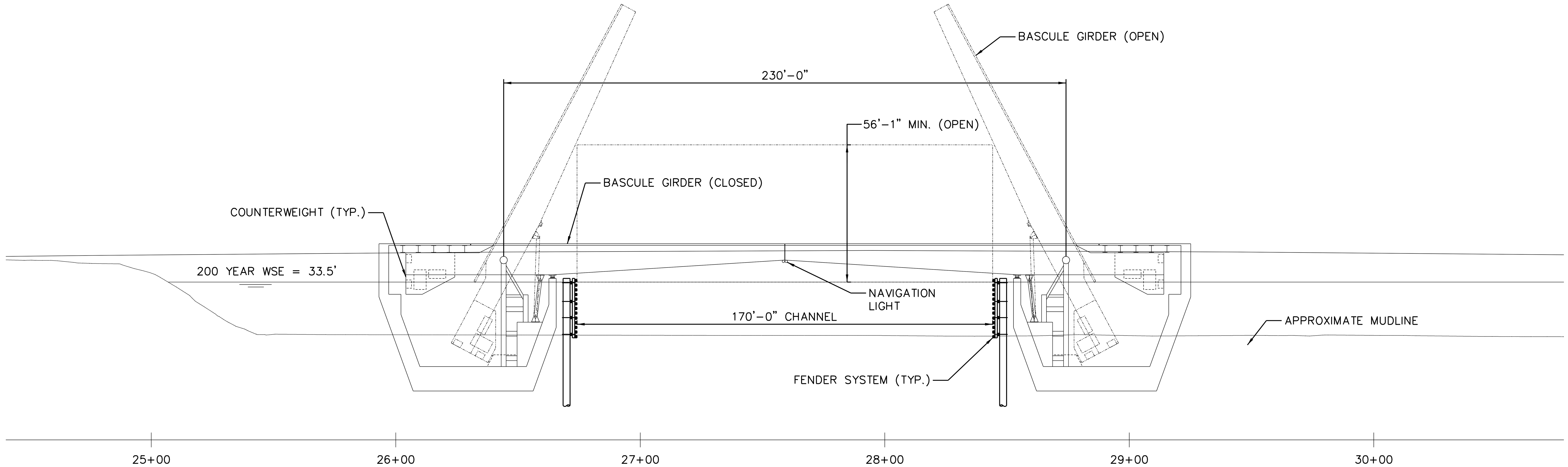
MARCH 2020



ELEVATION

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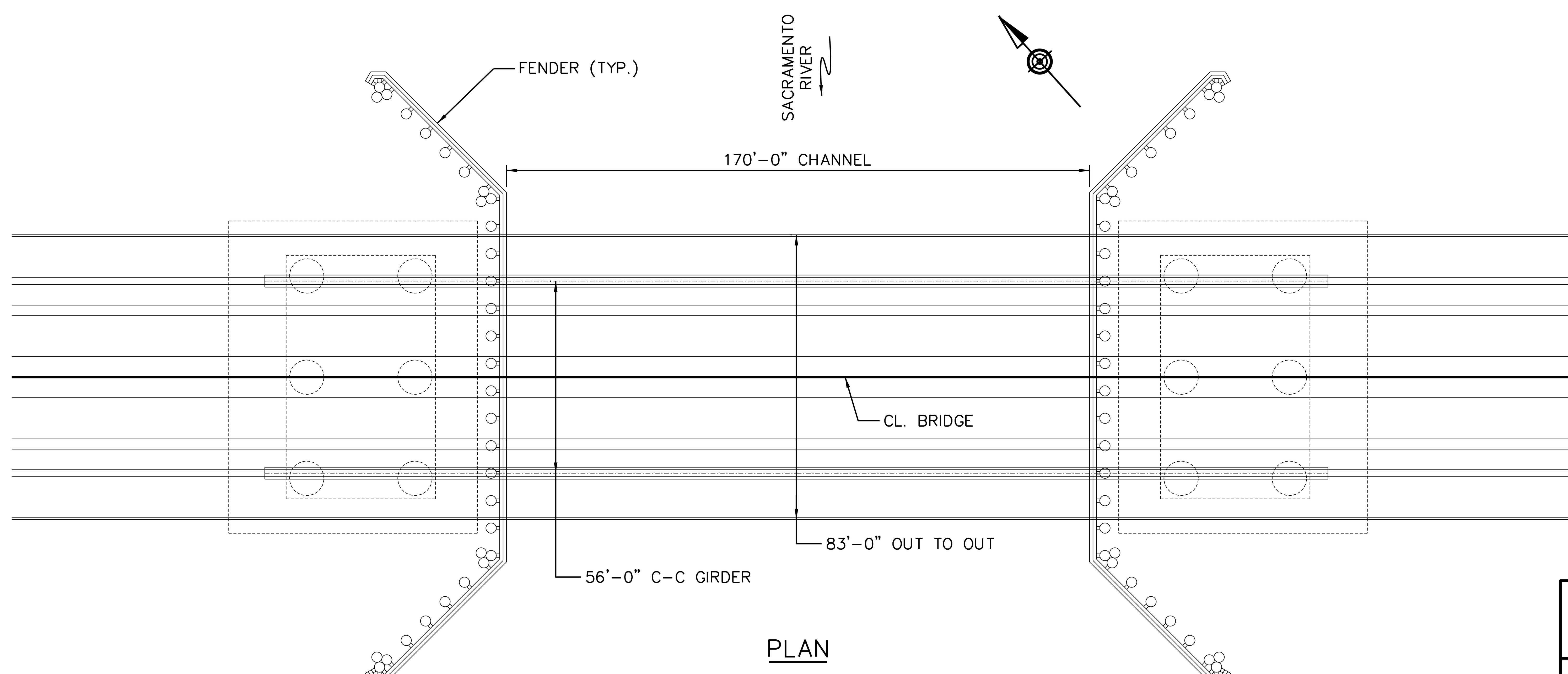

PLAN

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SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE B
PARTIALLY COUNTERWEIGHTED
BASCULE GIRDER SPAN
GENERAL PLAN AND ELEVATION

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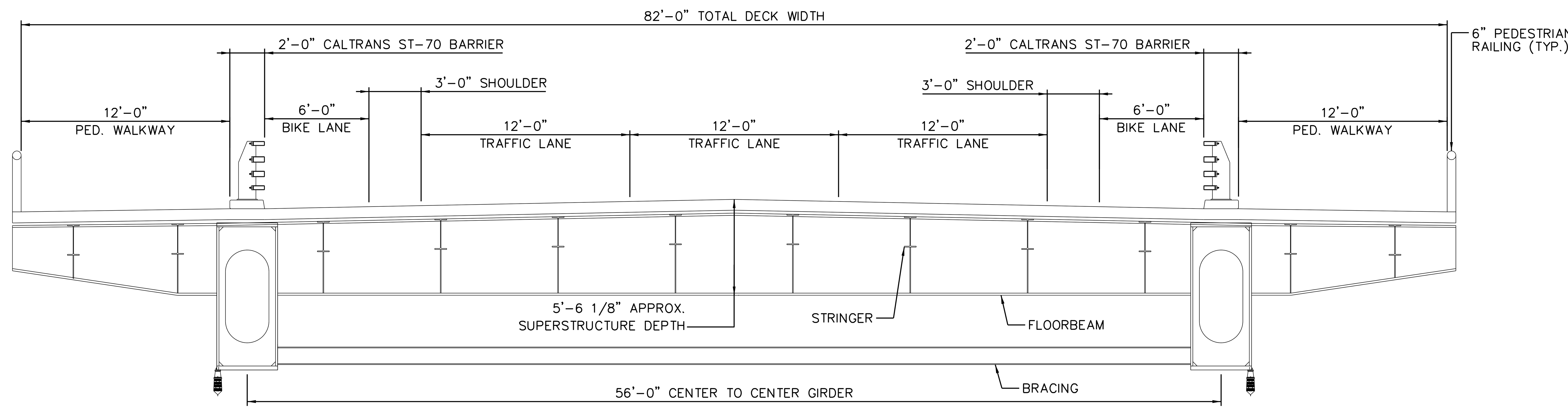

BASCULE GIRDER SPAN CROSS SECTION

5 0 5 10

SCALE IN FEET

BROADWAY BRIDGE PROJECT

ALTERNATIVES A AND B
BASCULE GIRDER SPAN
TYPICAL SECTIONS

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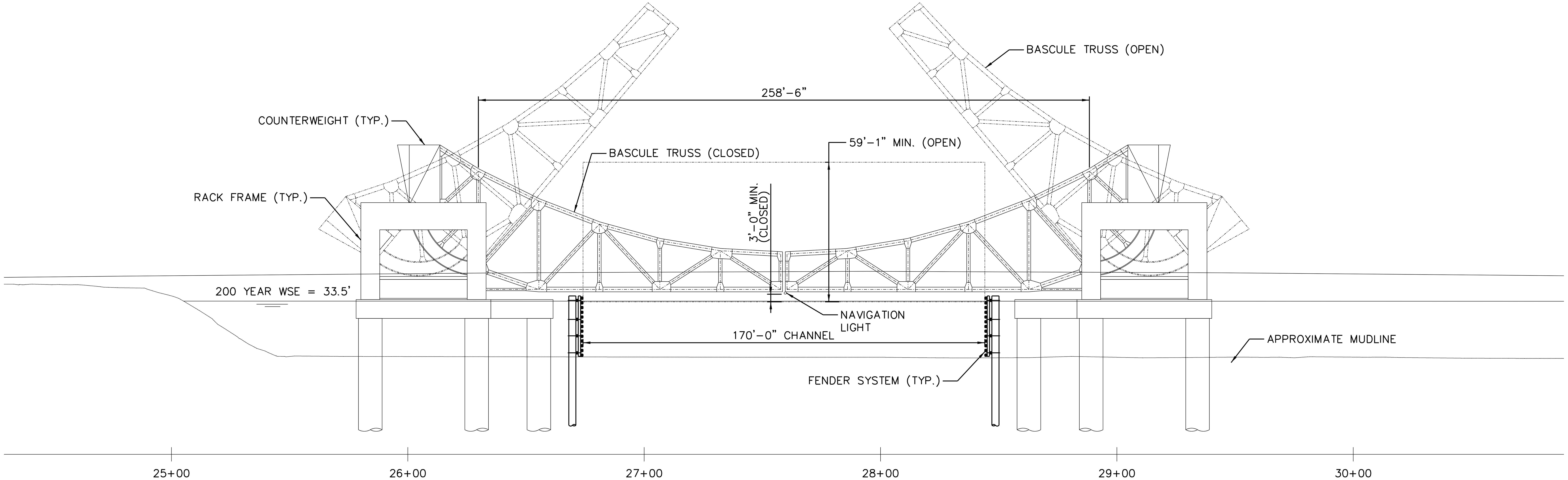

ELEVATION

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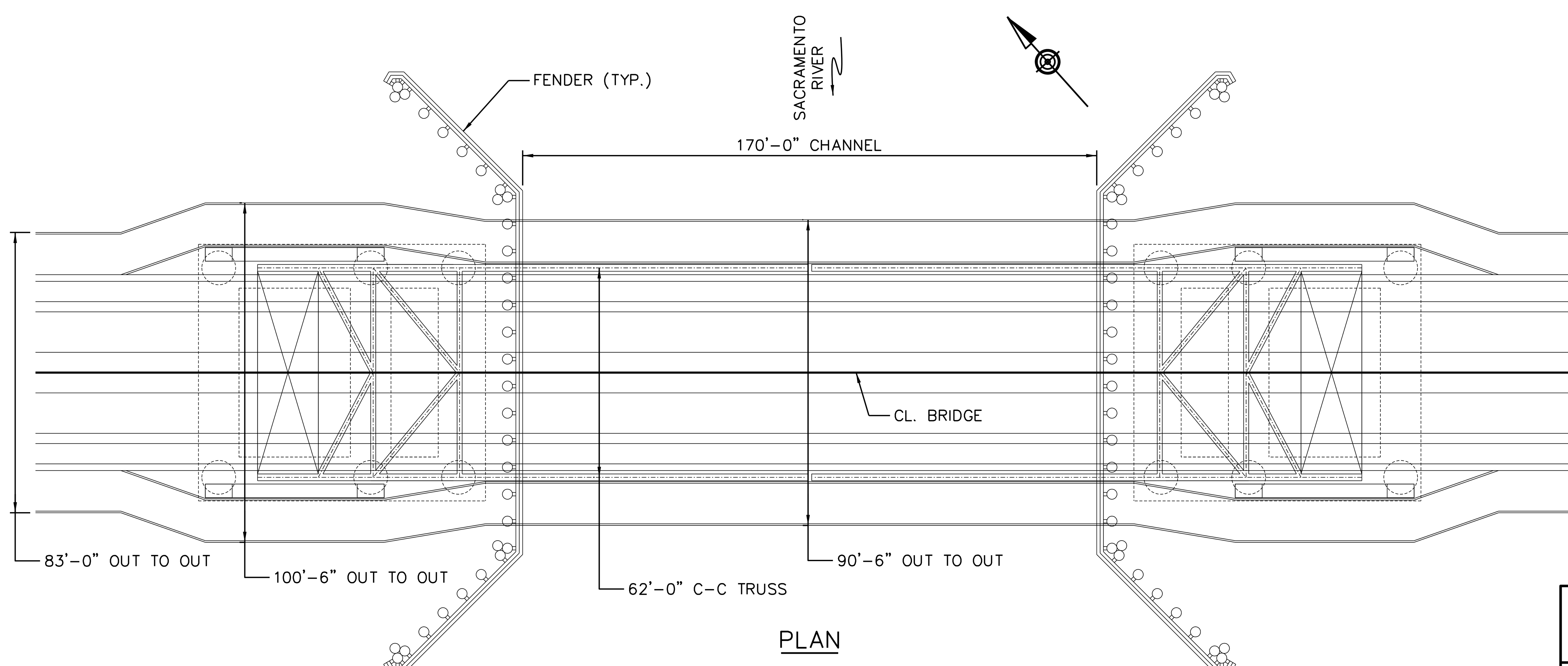

PLAN

20 0 20 40
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE C-1
FULLY COUNTERWEIGHTED
TWO LEAF ROLLING BASCULE TRUSS
GENERAL PLAN AND ELEVATION

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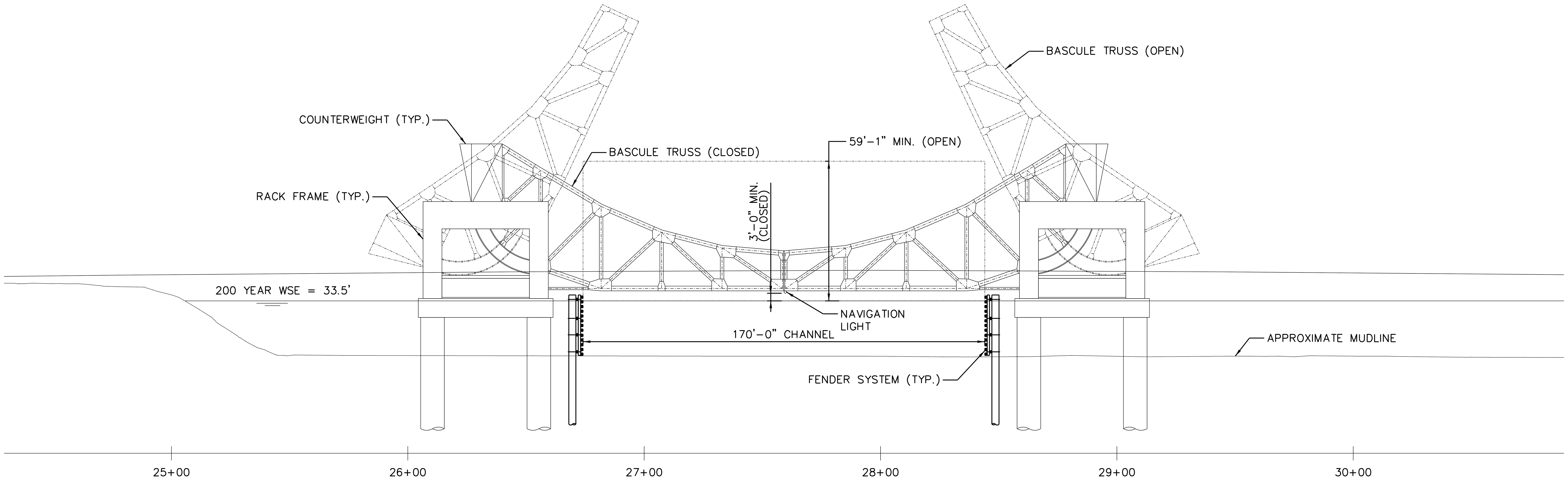

ELEVATION

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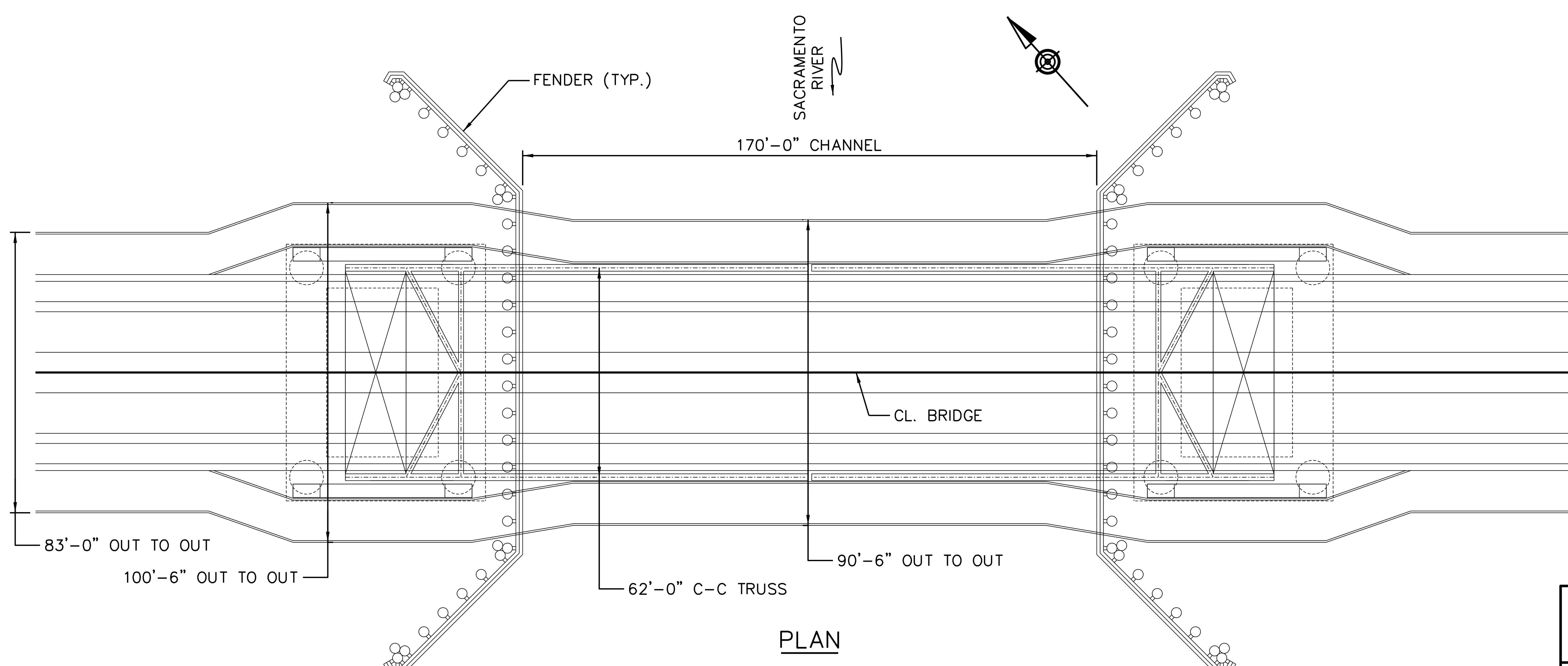
SCALE IN FEET



PLAN

20 0 20 40
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE C-2
FULLY COUNTERWEIGHTED
TWO LEAF ROLLING BASCULE TRUSS
GENERAL PLAN AND ELEVATION

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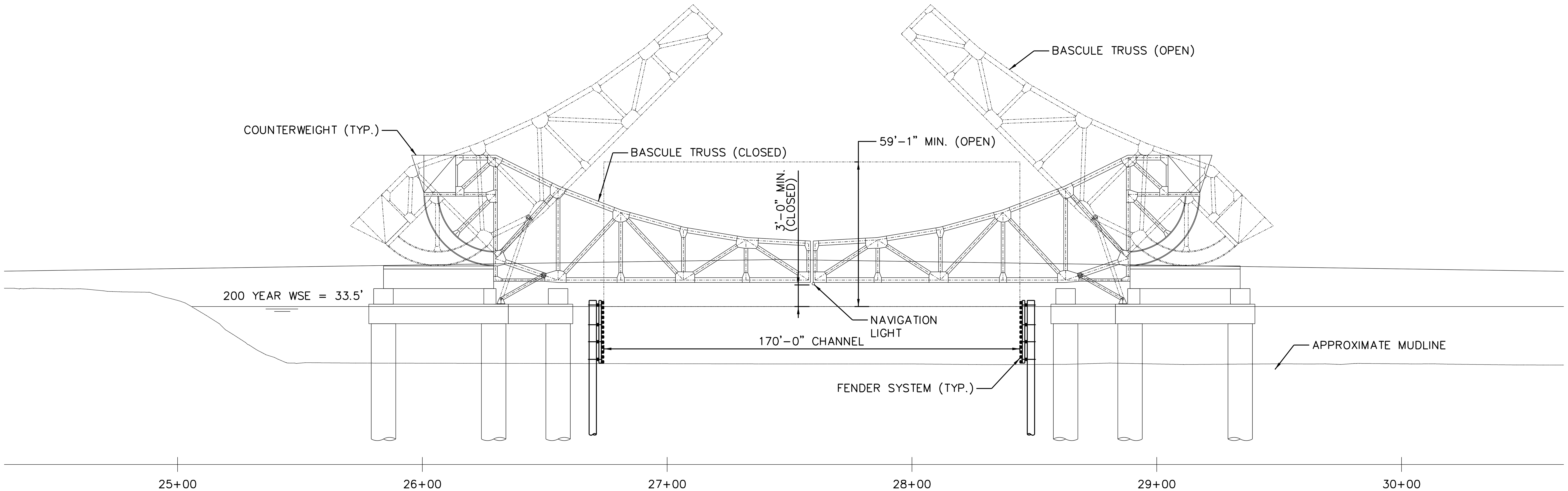

ELEVATION

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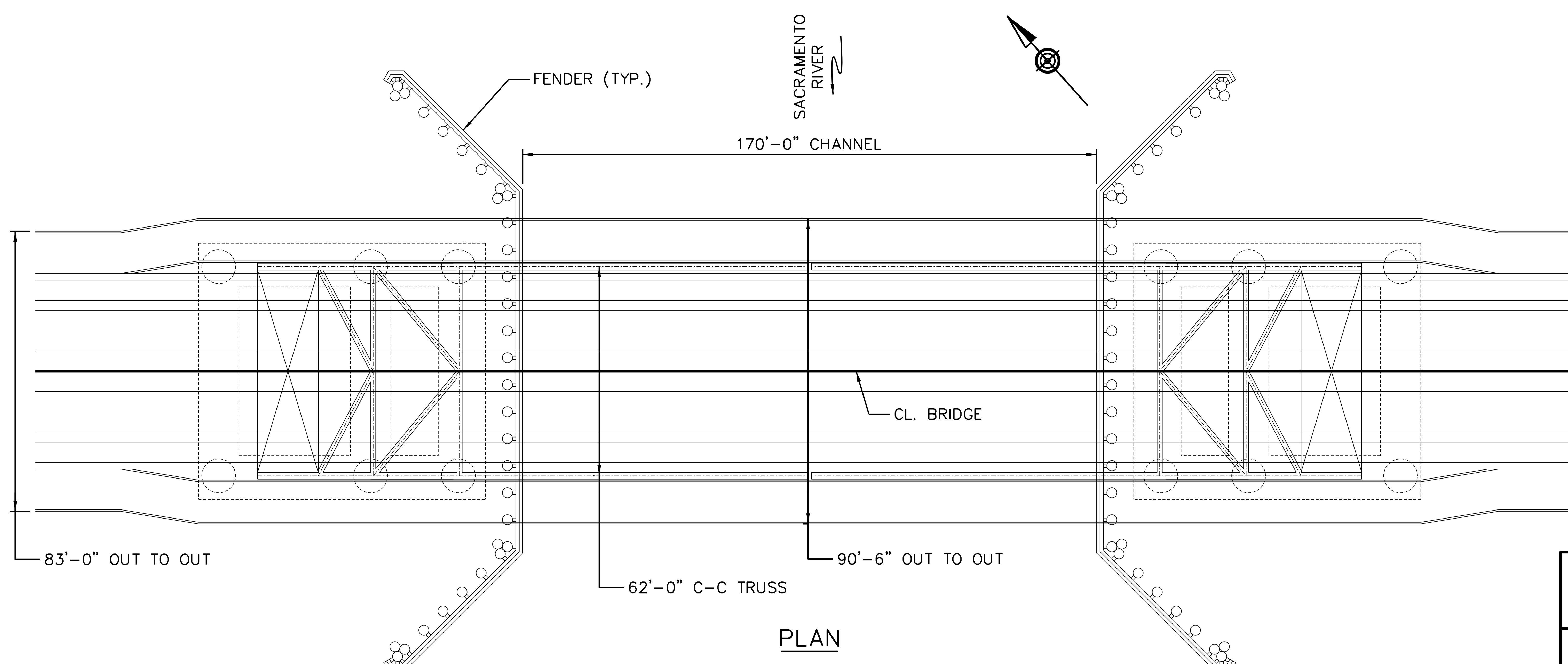
SCALE IN FEET



PLAN

20 0 20 40
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE D
PARTIALLY COUNTERWEIGHTED TWO LEAF ROLLING BASCULE TRUSS GENERAL PLAN AND ELEVATION

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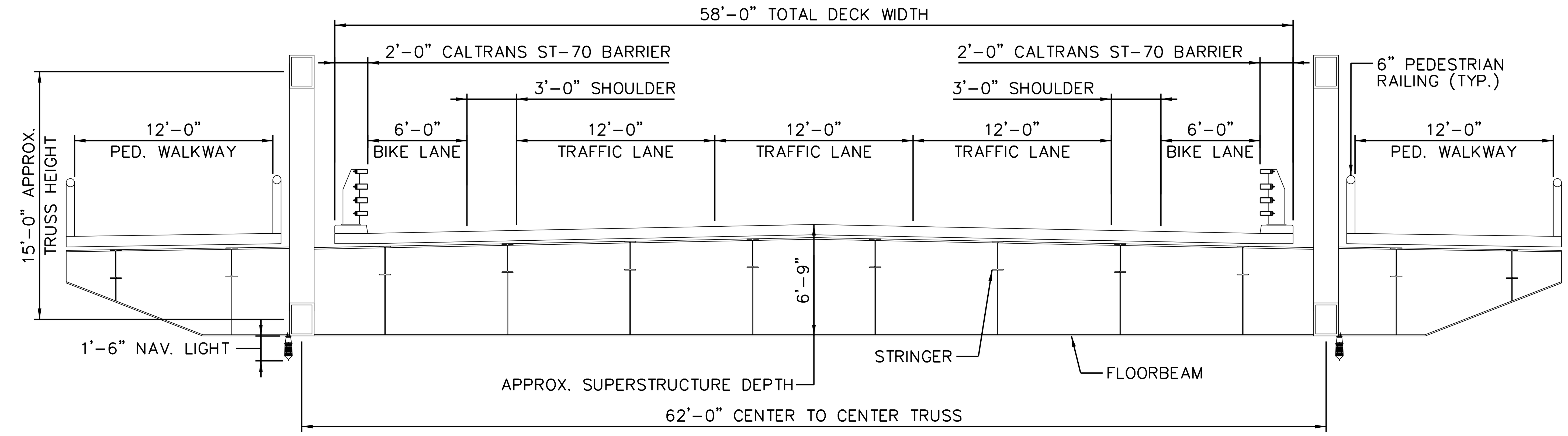
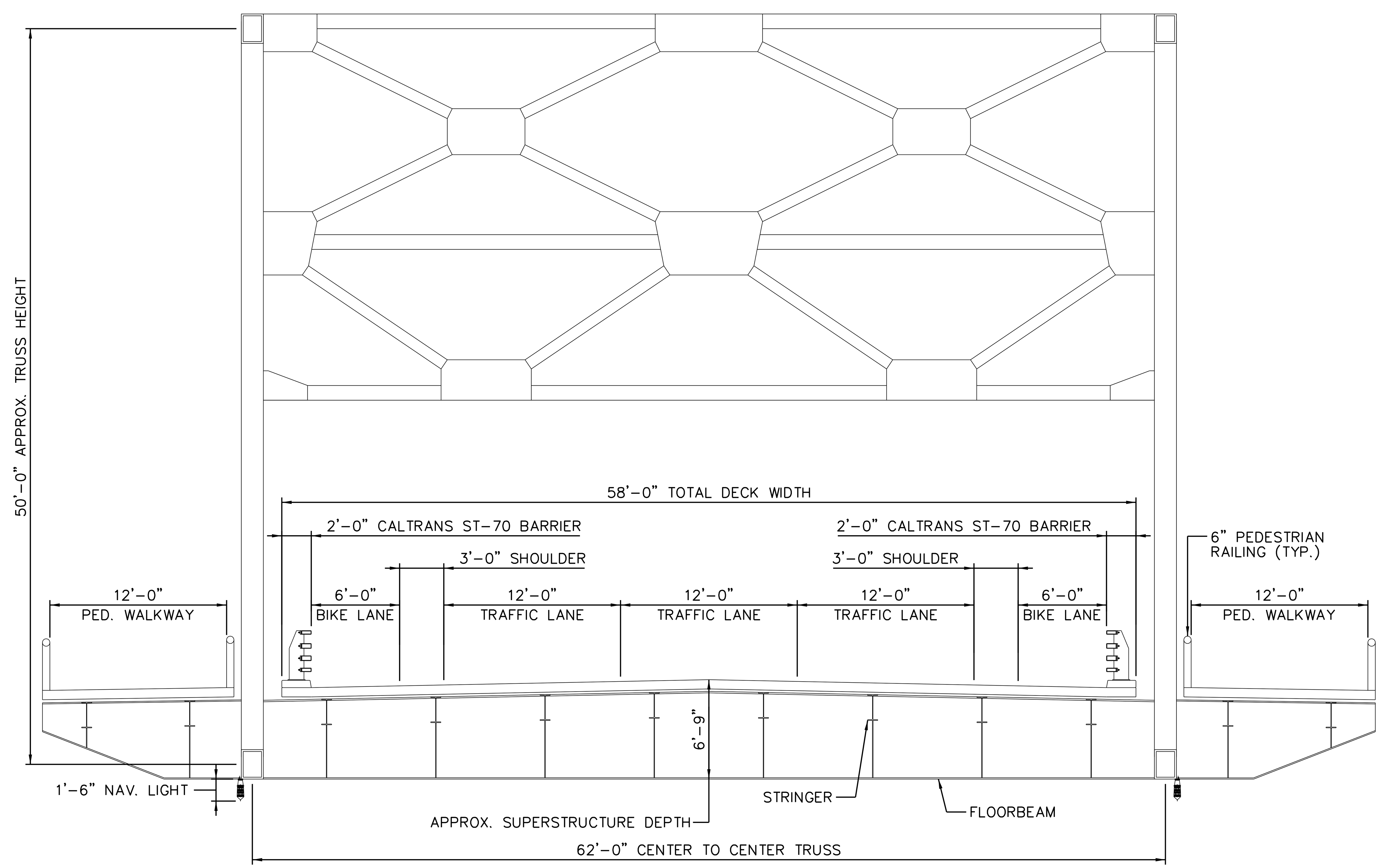


TWO LEAF BASCULE THROUGH TRUSS CROSS SECTION AT CENTER SPAN

5 0 5 10
SCALE IN FEET



TWO LEAF BASCULE THROUGH TRUSS CROSS SECTION AT END SPAN

5 0 5 10
SCALE IN FEET

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ALTERNATIVES C AND D
TWO LEAF ROLLING BASCULE TRUSS
TYPICAL SECTIONS

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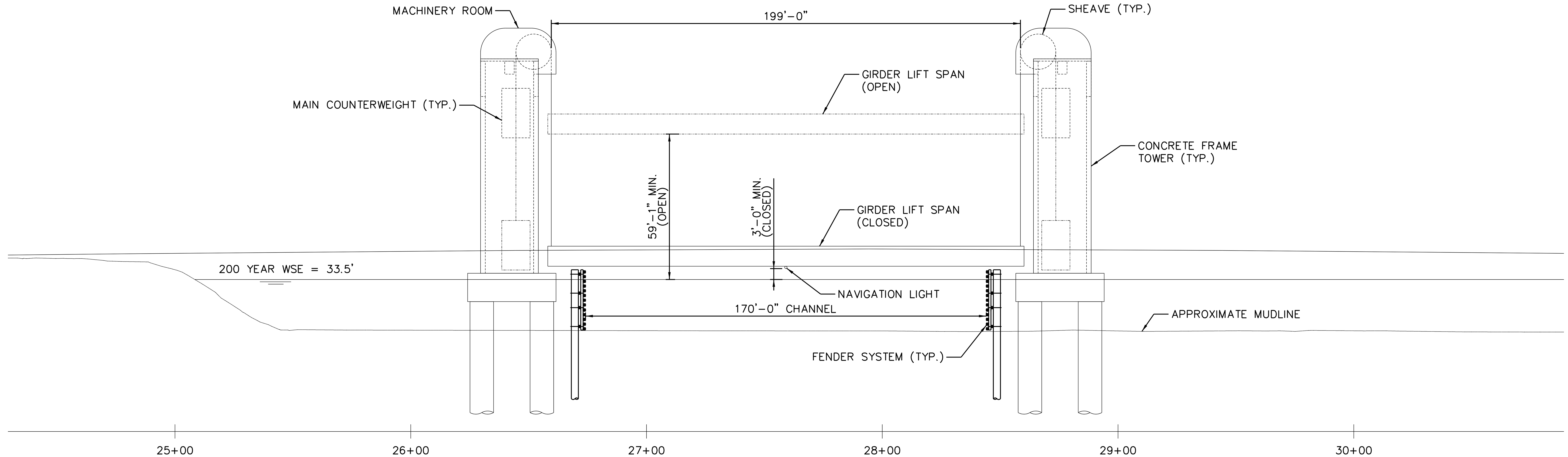

ELEVATION

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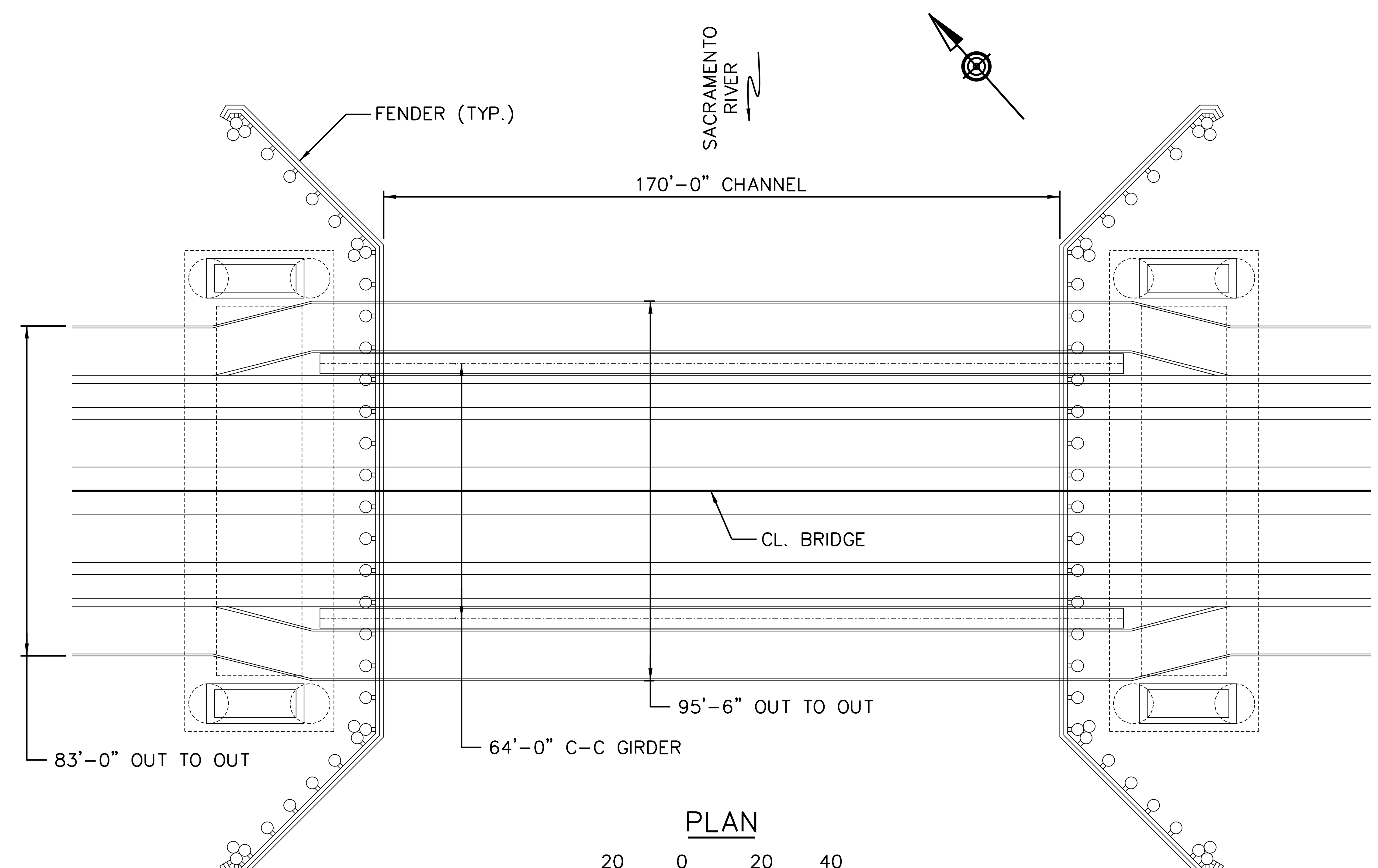
SCALE IN FEET



PLAN

20 0 20 40
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE E
VERTICAL LIFT GIRDER SPAN WITH CONCRETE FRAME TOWERS
GENERAL PLAN AND ELEVATION

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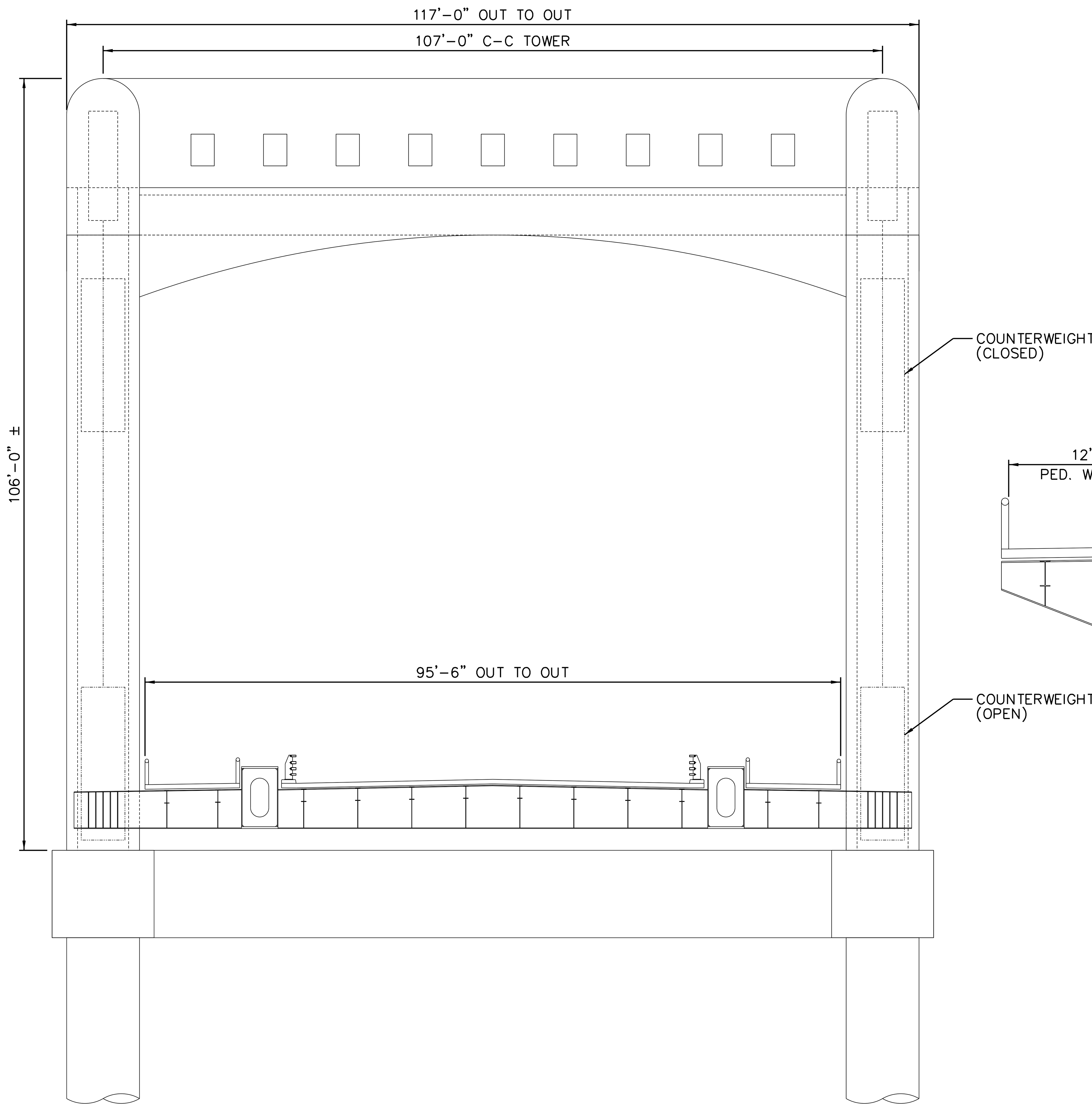

VERTICAL LIFT CONCRETE FRAME TOWER CROSS SECTION

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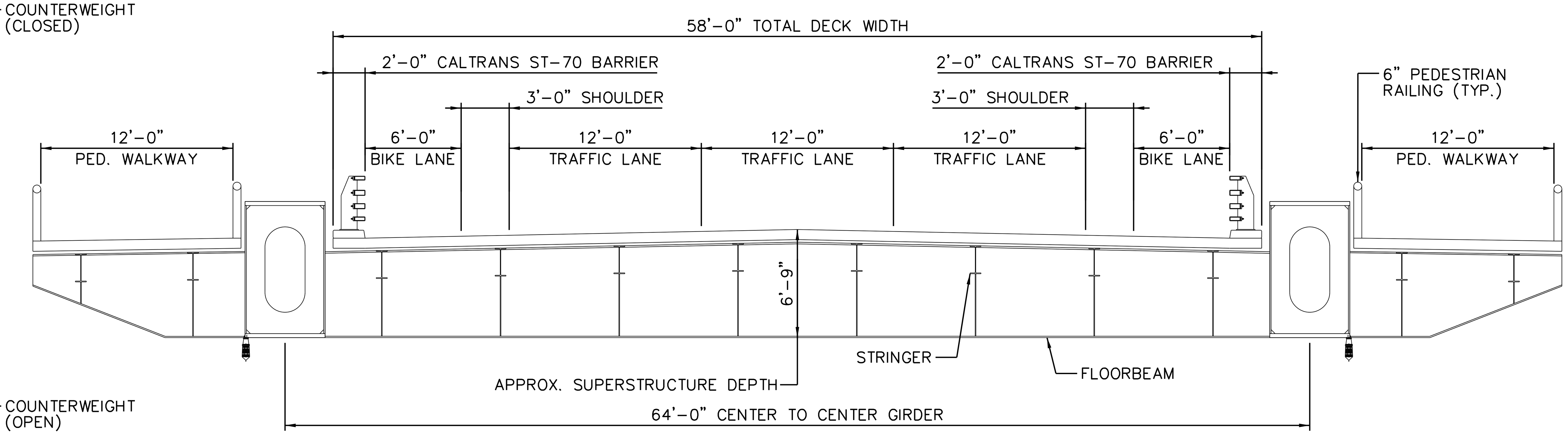
SCALE IN FEET



VERTICAL LIFT GIRDER SPAN CROSS SECTION

5 0 5 10
SCALE IN FEET

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ALTERNATIVE E
VERTICAL LIFT GIRDER SPAN WITH
CONCRETE FRAME TOWERS
TYPICAL SECTIONS

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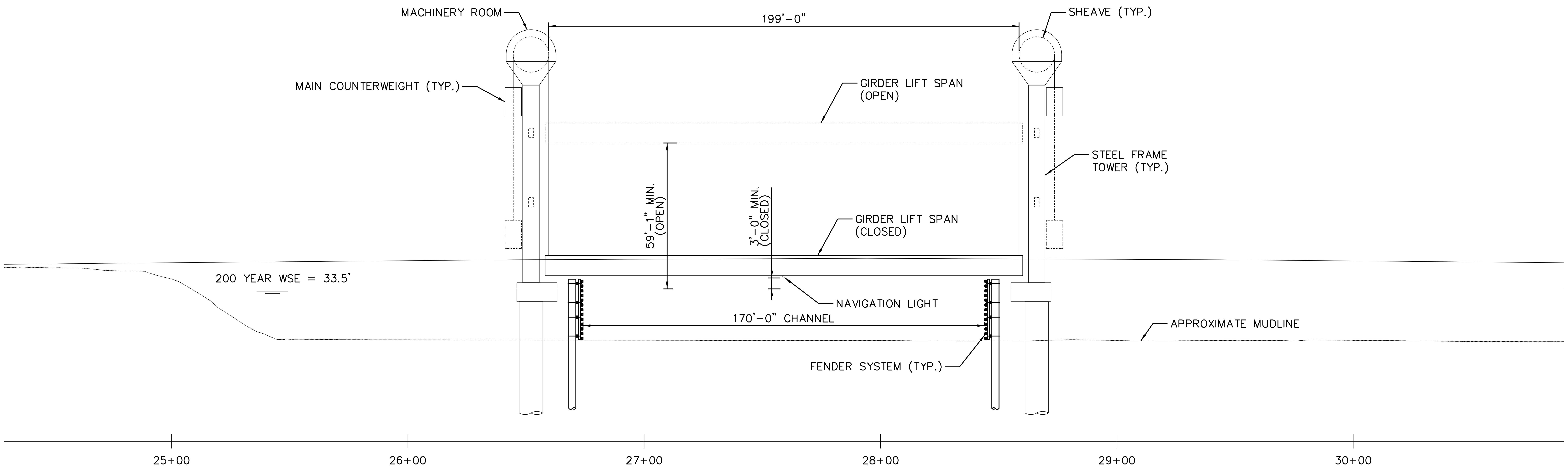

ELEVATION

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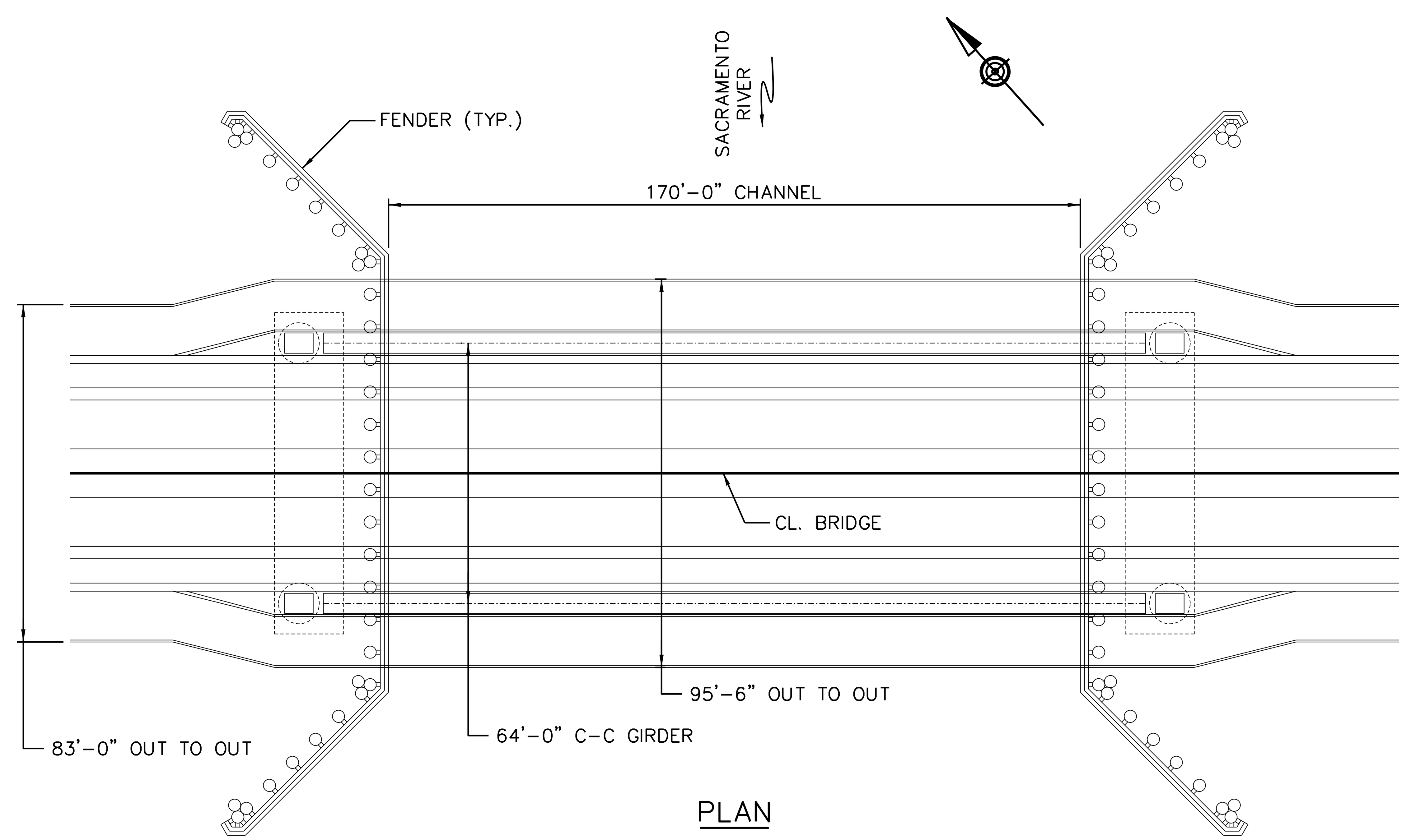

PLAN

20 0 20 40
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE F
VERTICAL LIFT GIRDER SPAN WITH STEEL FRAME TOWERS
GENERAL PLAN AND ELEVATION

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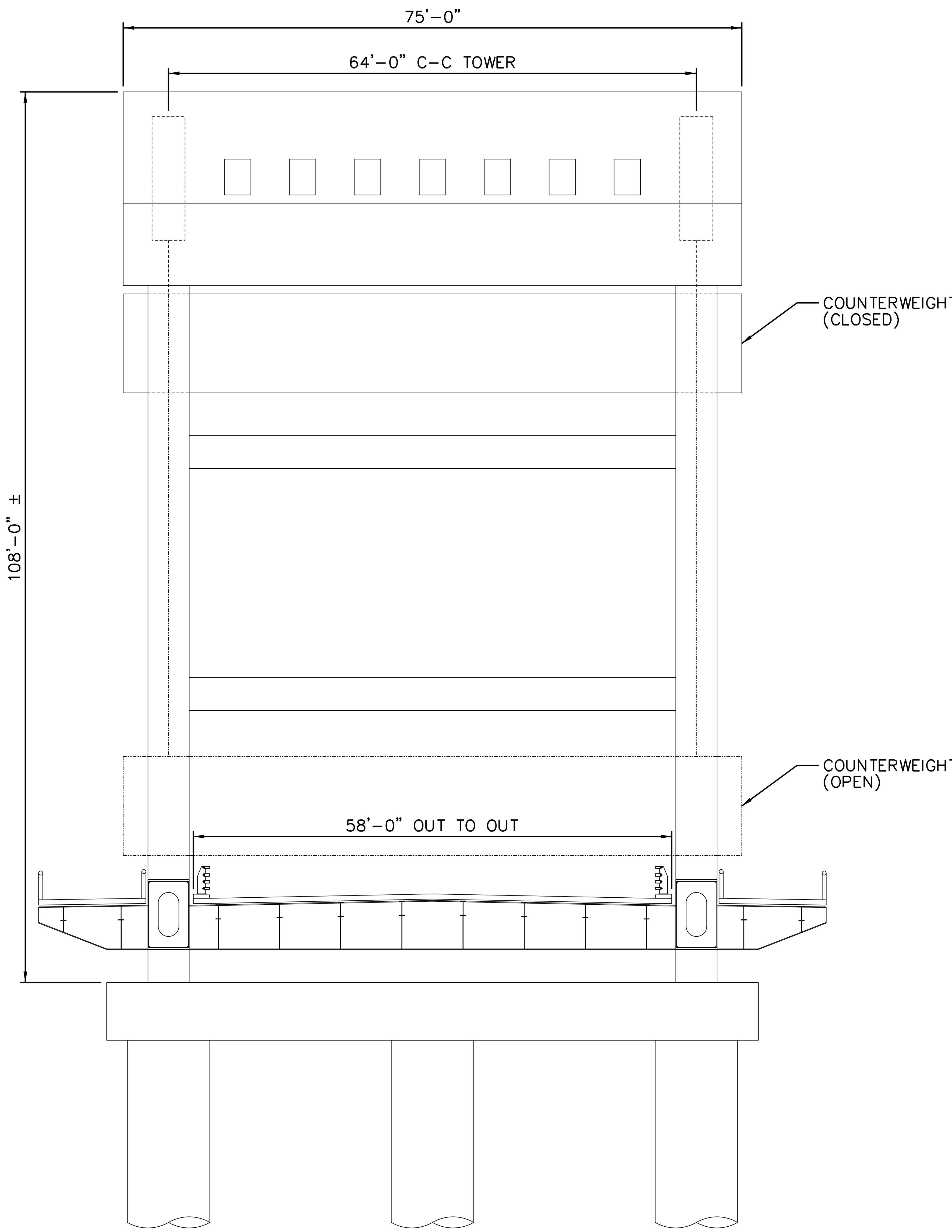

VERTICAL LIFT STEEL FRAME TOWER CROSS SECTION

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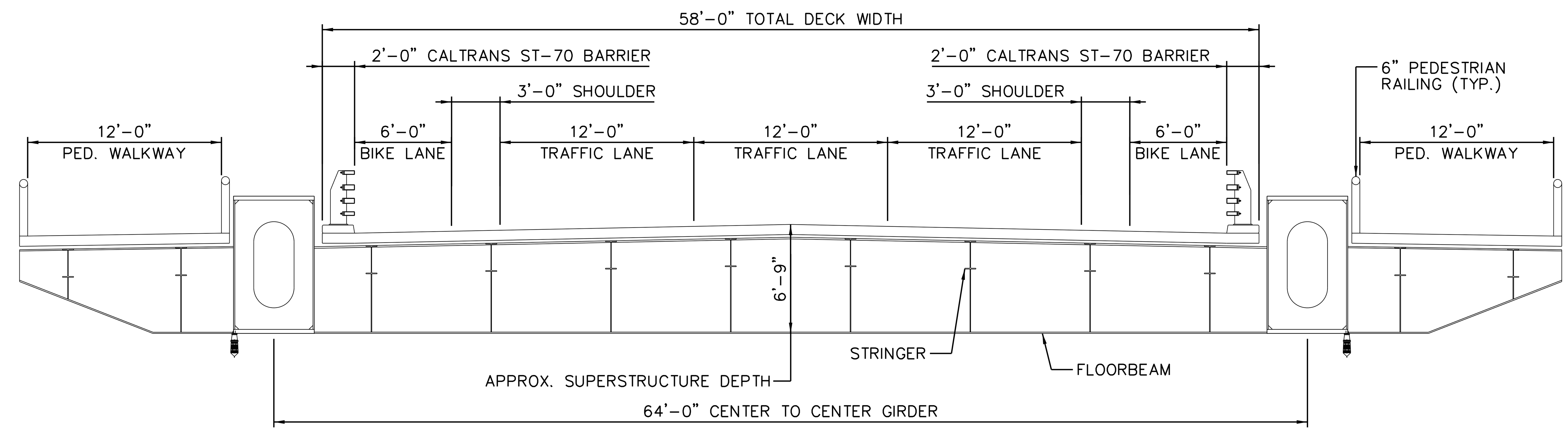

VERTICAL LIFT GIRDER SPAN CROSS SECTION

5 0 5 10
SCALE IN FEET

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ALTERNATIVE F
VERTICAL LIFT GIRDER SPAN
WITH STEEL FRAME TOWERS
TYPICAL SECTIONS

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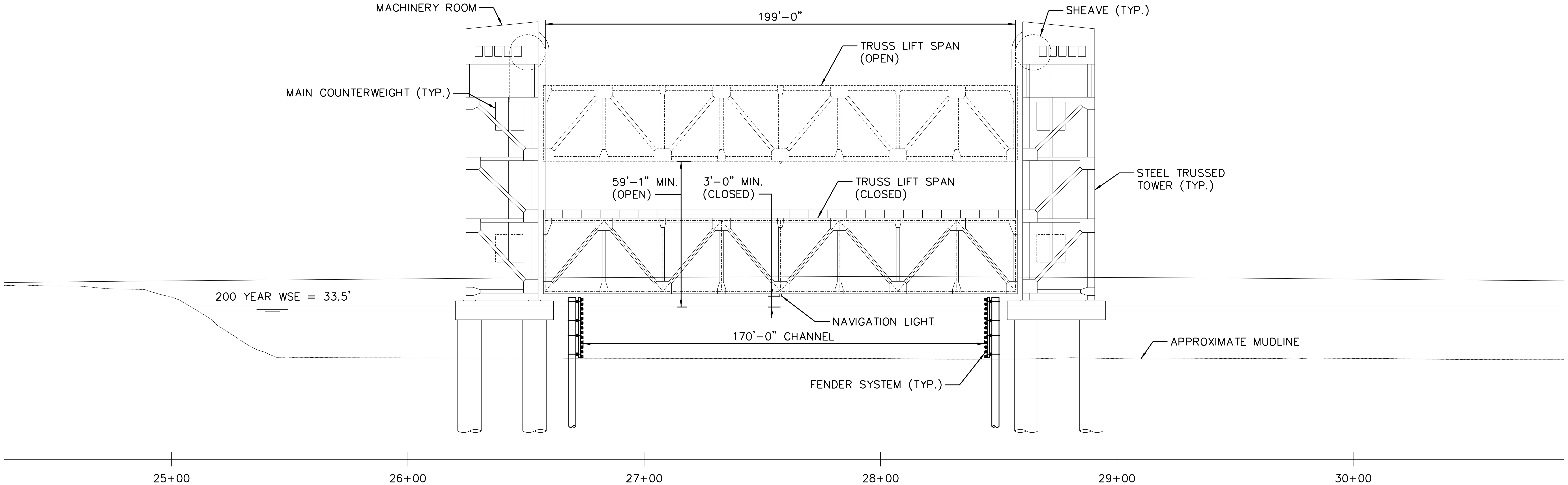

ELEVATION

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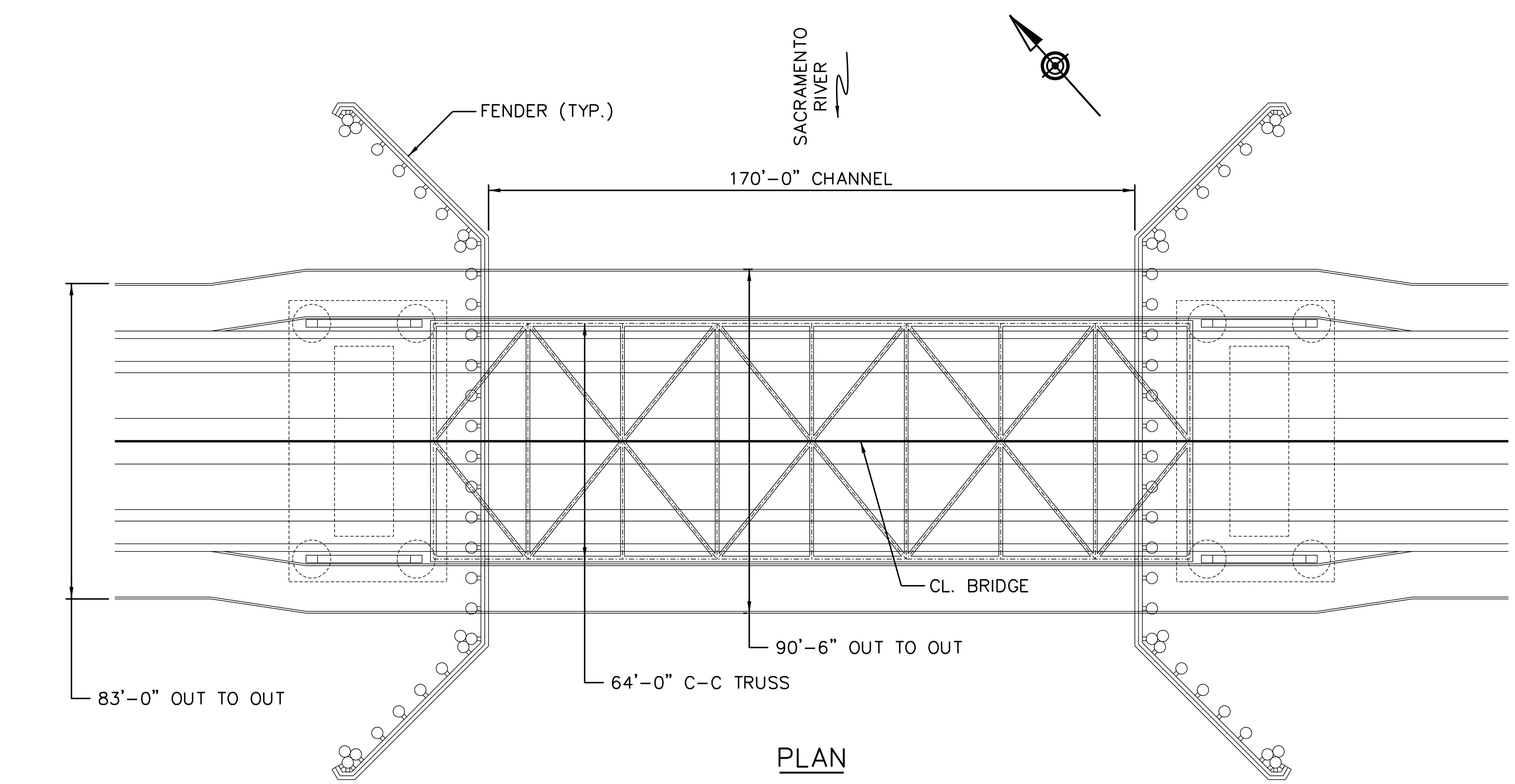

PLAN

20 0 20 40
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE G
VERTICAL LIFT TRUSS SPAN
WITH TRUSSED TOWERS
GENERAL PLAN AND ELEVATION

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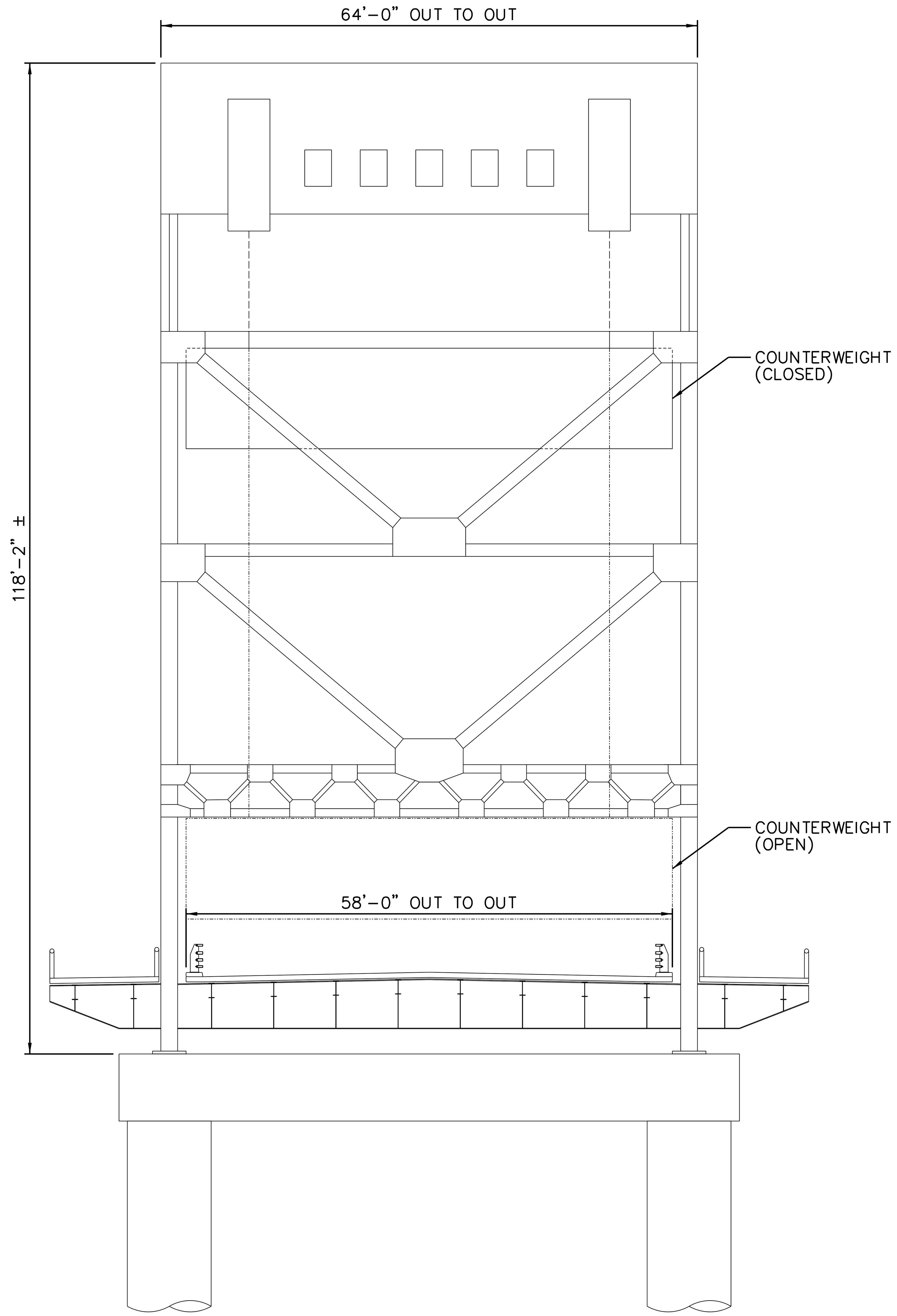
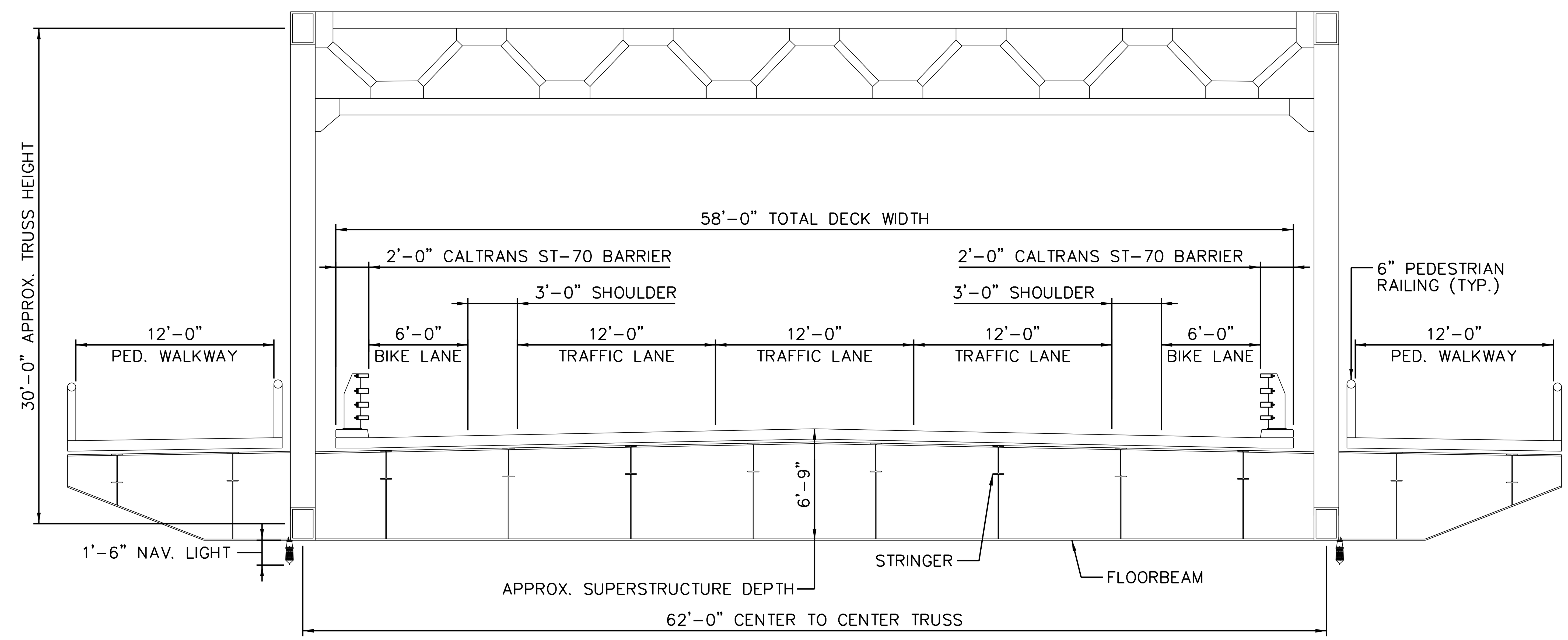


VERTICAL LIFT STEEL TRUSSED TOWER CROSS SECTION

10 0 10 20
SCALE IN FEET



THROUGH TRUSS CROSS SECTION

5 0 5 10
SCALE IN FEET

BROADWAY BRIDGE PROJECT

ALTERNATIVE G
VERTICAL LIFT TRUSS SPAN WITH TRUSSED TOWERS TYPICAL SECTIONS

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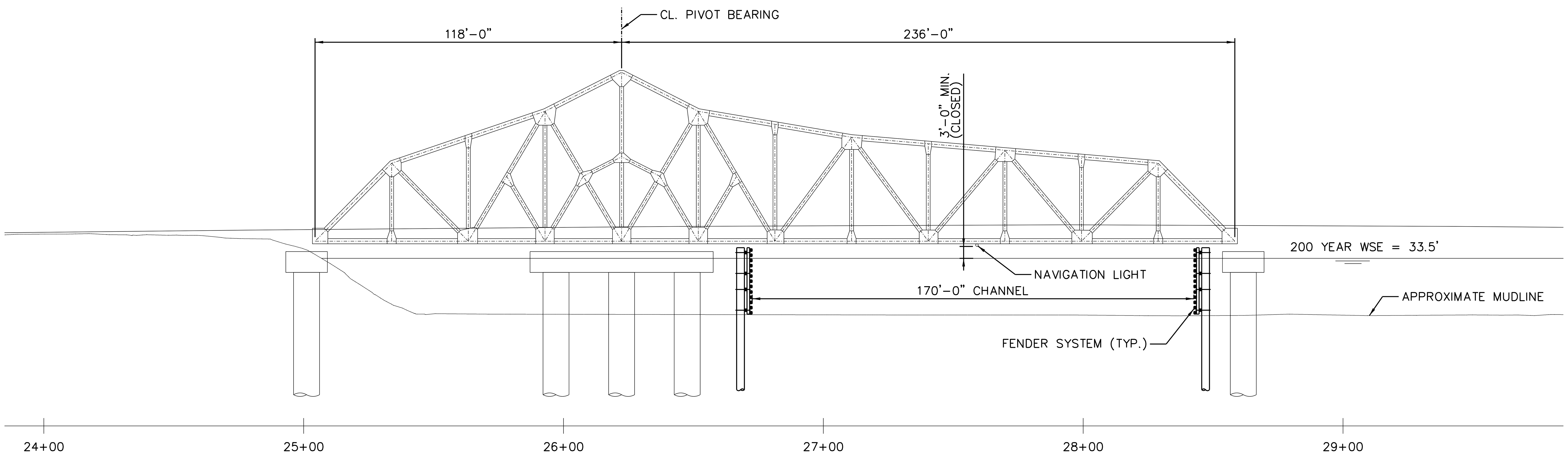
MARCH 2020



ELEVATION

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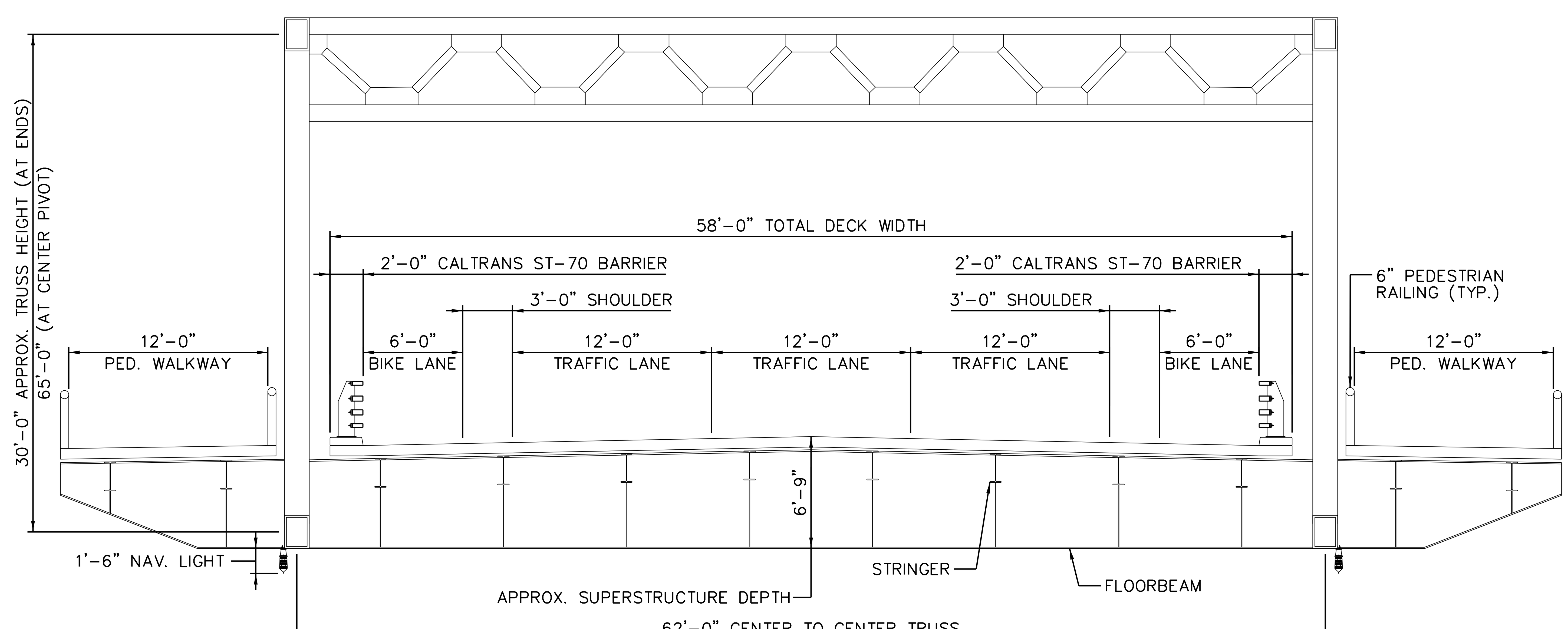
SCALE IN FEET



THROUGH TRUSS CROSS SECTION

(BOBTAIL SWING TRUSS END SECTION SHOWN VISUALLY, BOBTAIL SWING TRUSS AT CENTER PIVOT SIMILAR AS NOTED)

5 0 5 10
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT	
ALTERNATIVE H-1 BOBTAIL SWING THROUGH TRUSS SPANS ELEVATION AND TYPICAL SECTION	
MODJESKI and MASTERS Experience great bridges.	SHEET 14 OF 21
	MARCH 2020

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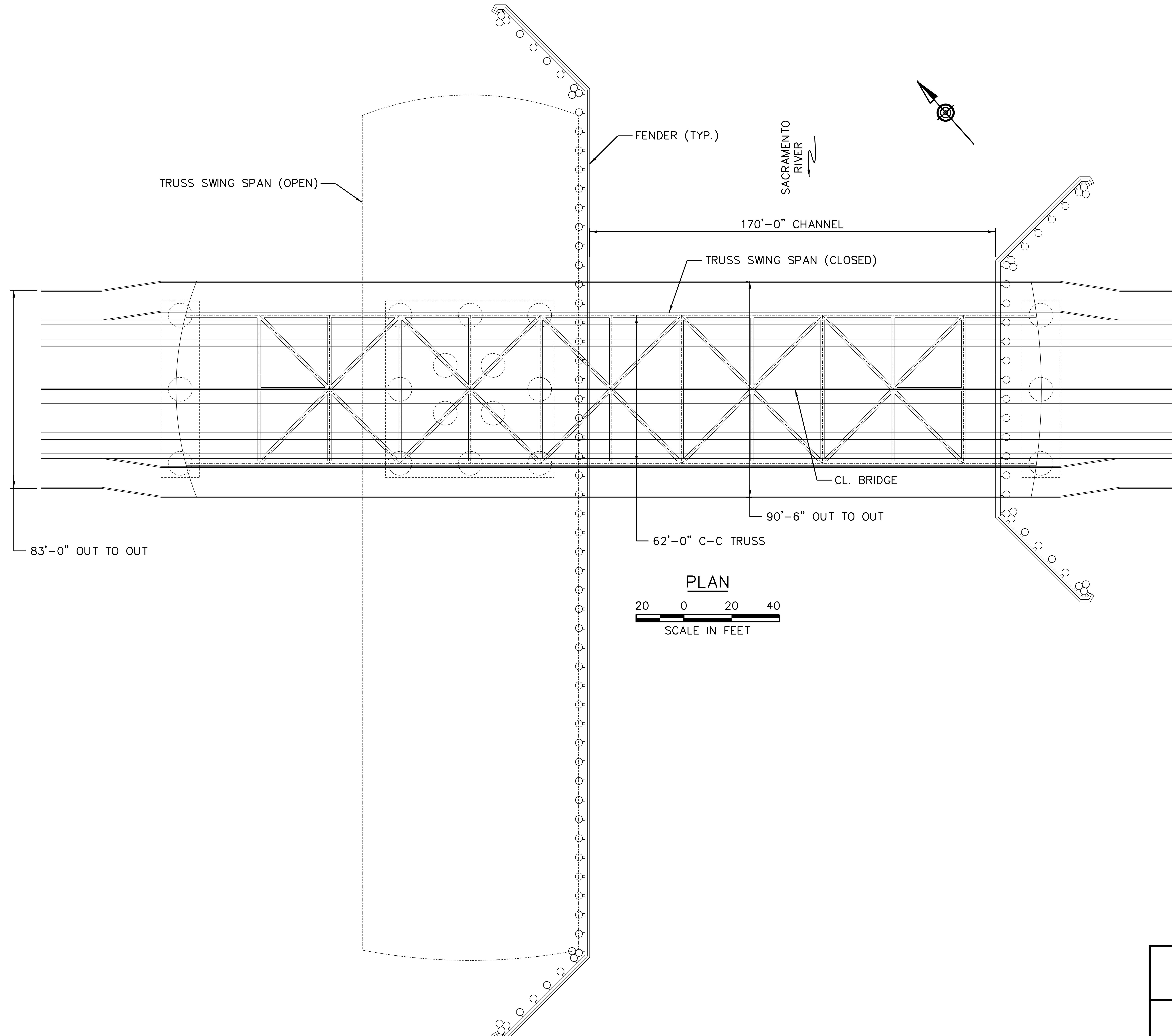
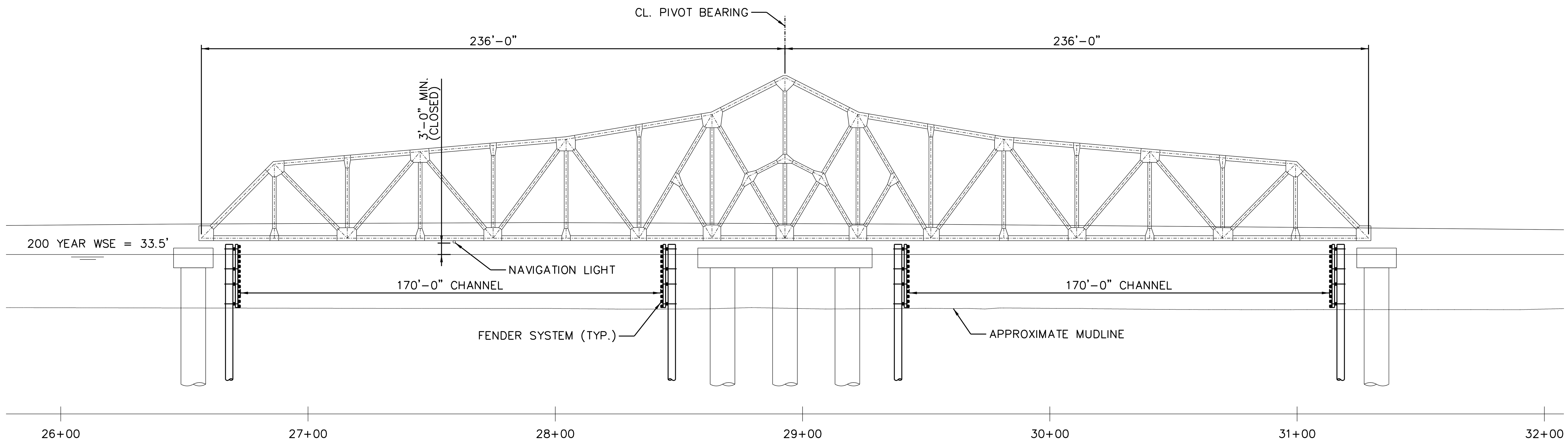


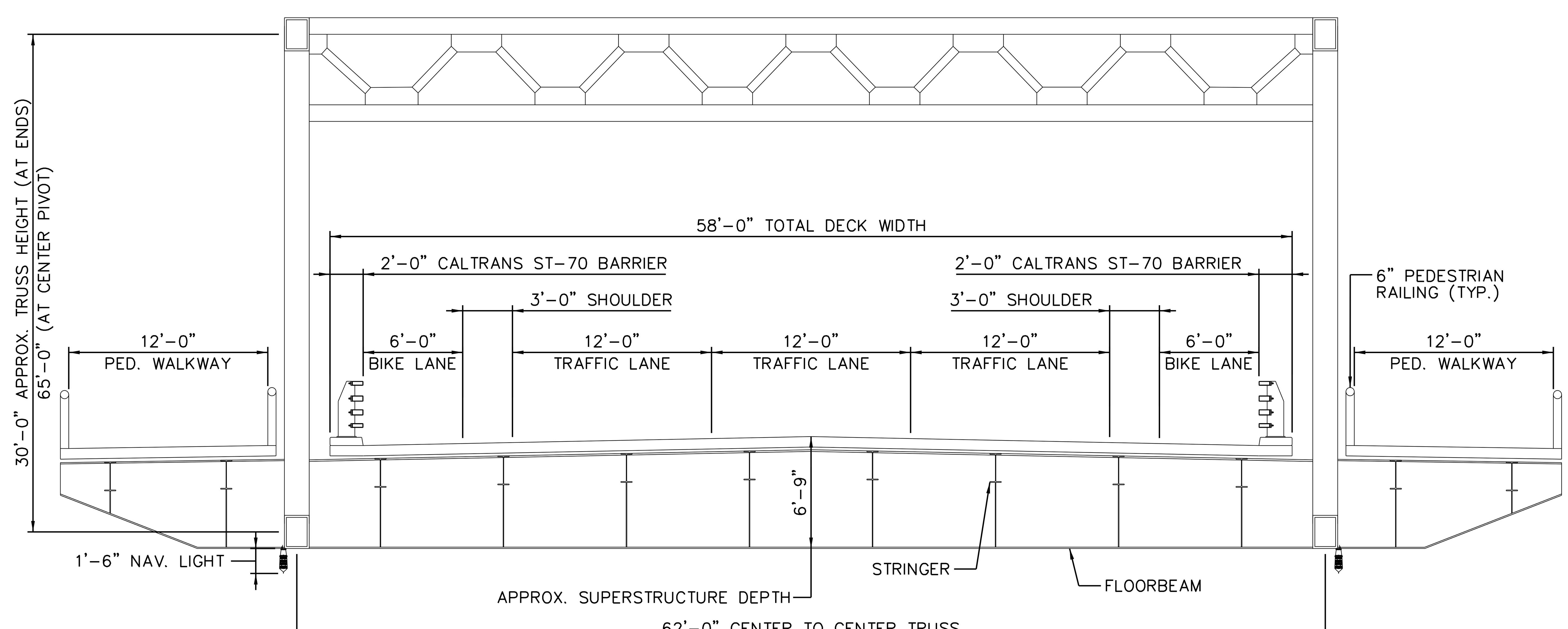
NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT	
ALTERNATIVE H-1 BOBTAIL SWING THROUGH TRUSS SPANS GENERAL PLAN	
MODJESKI and MASTERS Experience great bridges.	SHEET 15 OF 21
	MARCH 2020



ELEVATION

20 0 20 40
SCALE IN FEET



THROUGH TRUSS CROSS SECTION
(BOBTAIL SWING TRUSS END SECTION SHOWN VISUALLY,
BOBTAIL SWING TRUSS AT CENTER PIVOT SIMILAR AS NOTED)

5 0 5 10
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE H-2
SWING THROUGH
TRUSS SPANS
ELEVATION AND TYPICAL SECTION

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MARCH 2020

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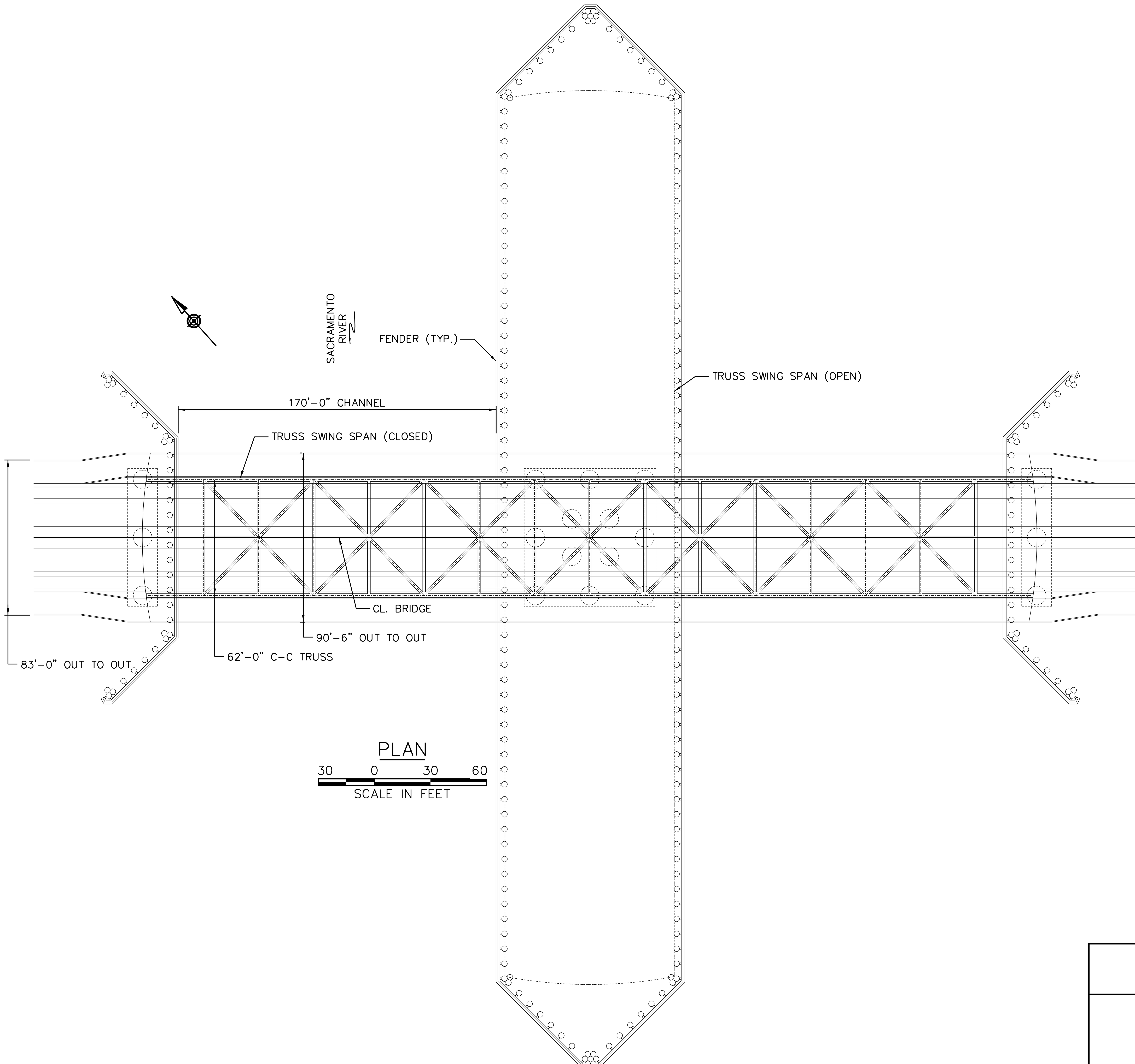
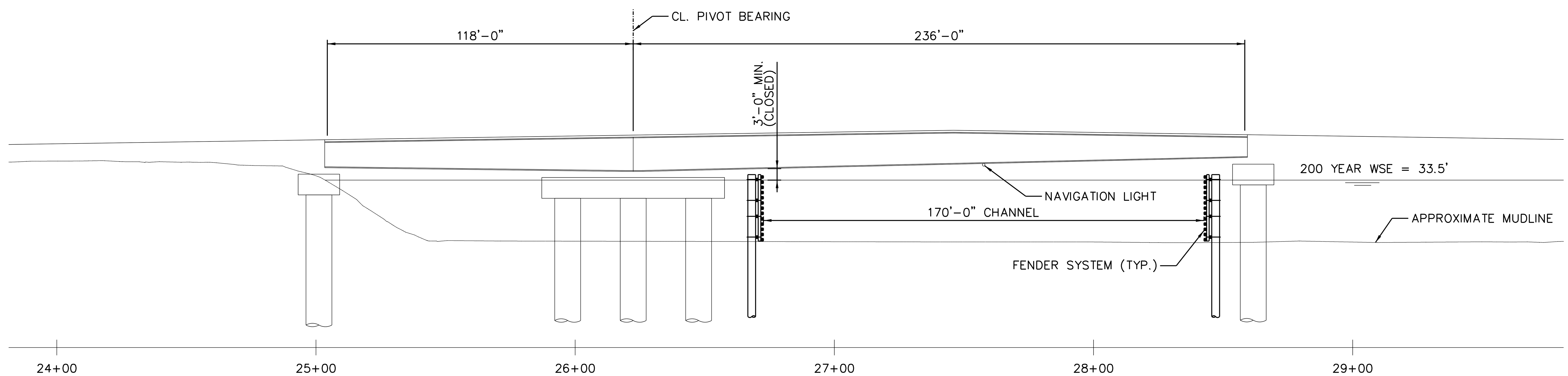


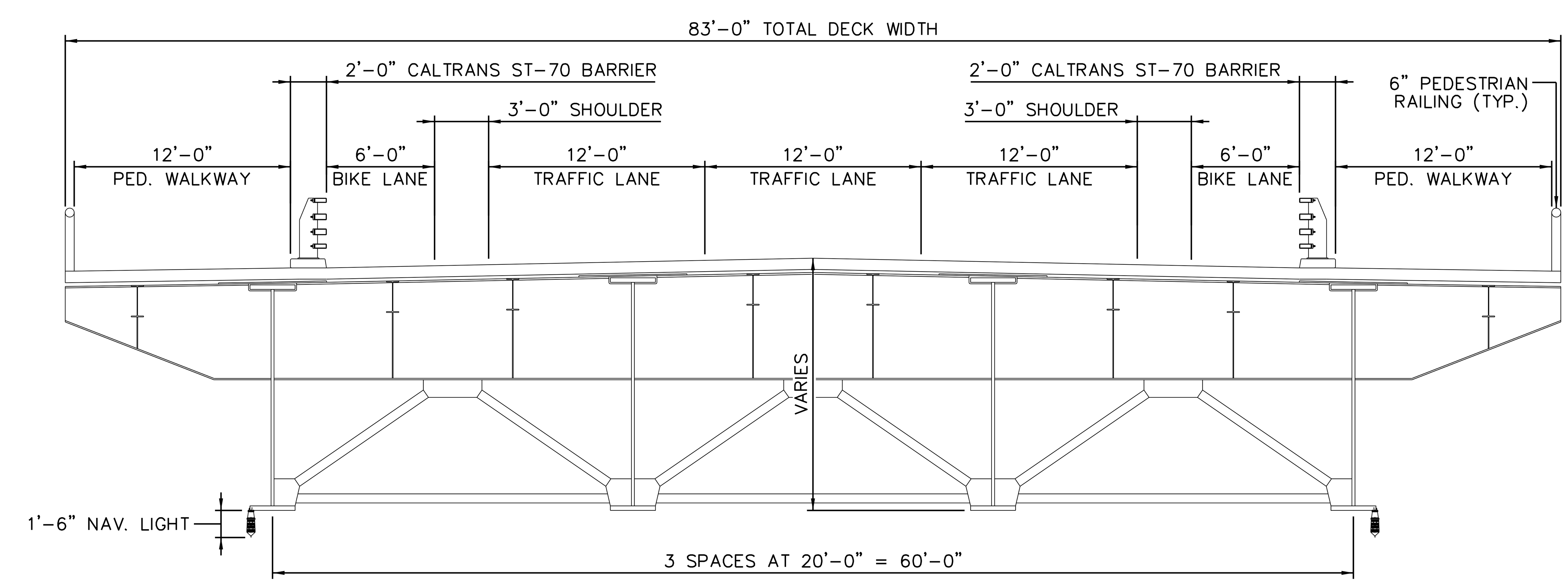
NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT	
ALTERNATIVE H-2 SWING THROUGH TRUSS SPANS GENERAL PLAN	
MODJESKI and MASTERS Experience great bridges.	SHEET 17 OF 21 MARCH 2020



ELEVATION

20 0 20 40
SCALE IN FEET



BOBTAIL SWING DECK GIRDER CROSS SECTION

5 0 5 10
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

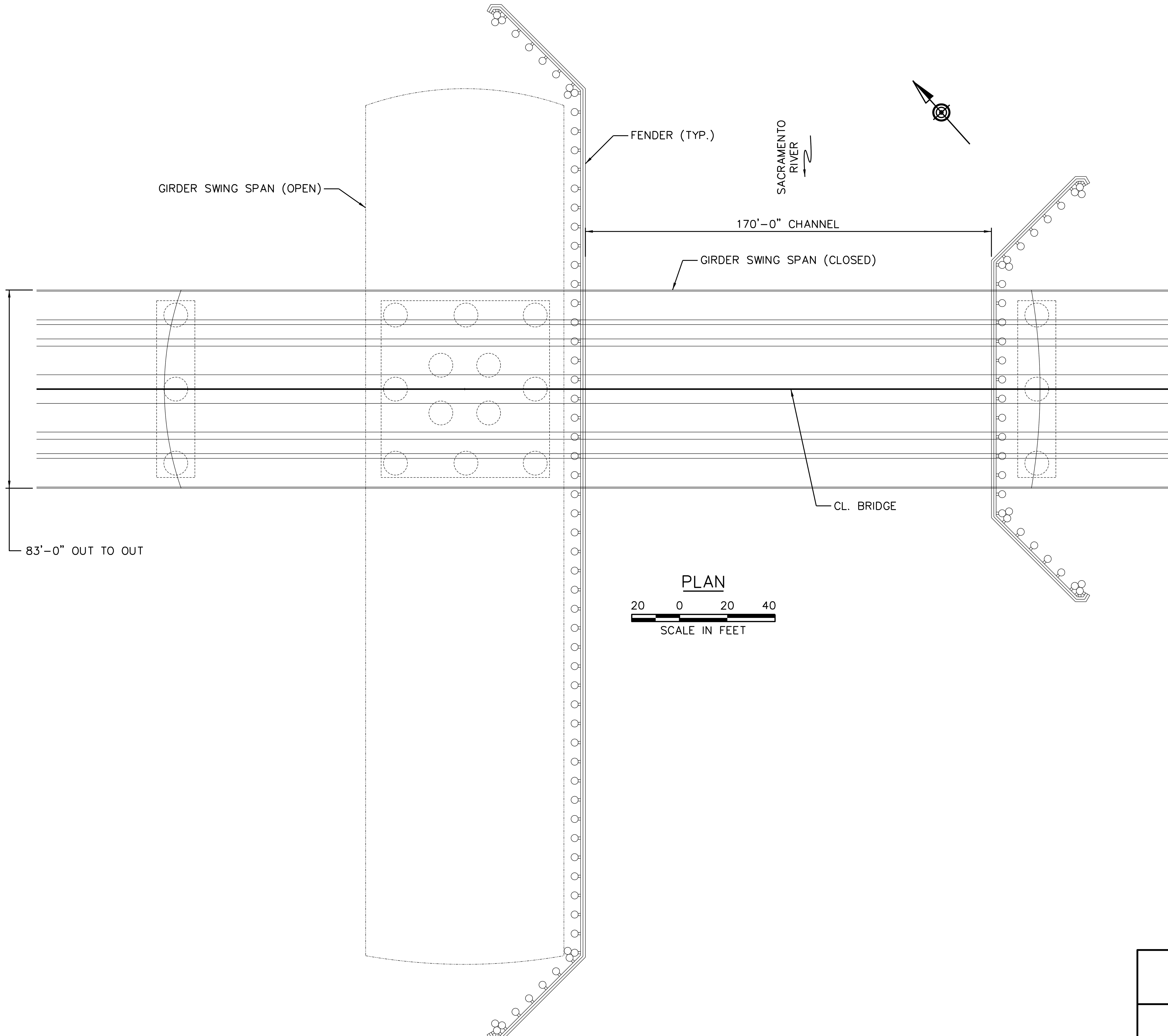
BROADWAY BRIDGE PROJECT

ALTERNATIVE I-1
BOBTAIL SWING DECK GIRDER SPANS
ELEVATION AND TYPICAL SECTION

MODJESKI and MASTERS
Experience great bridges.

SHEET 18 OF 21

MARCH 2020



NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

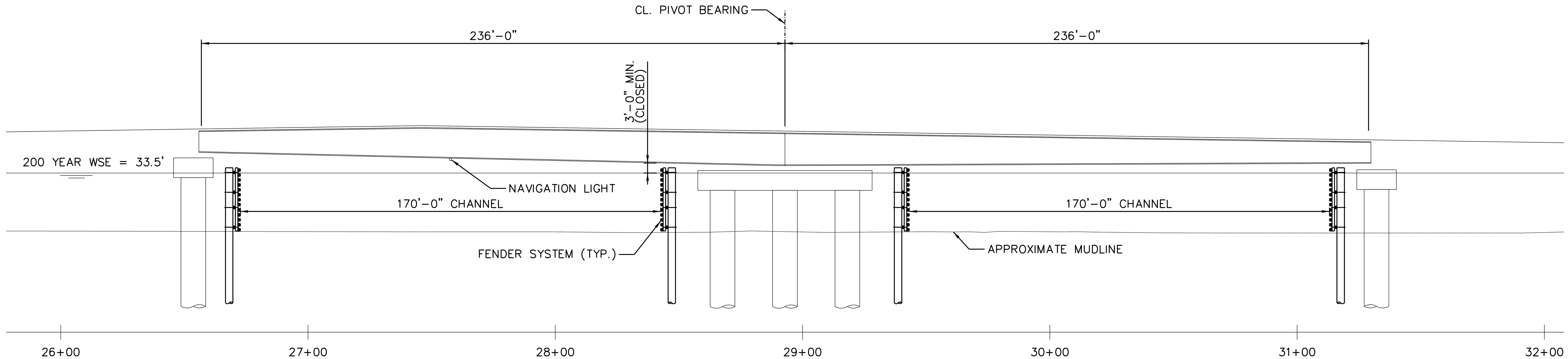
BROADWAY BRIDGE PROJECT

ALTERNATIVE I-1
BOBTAIL SWING DECK GIRDER SPANS
GENERAL PLAN

MODJESKI and MASTERS
Experience great bridges.

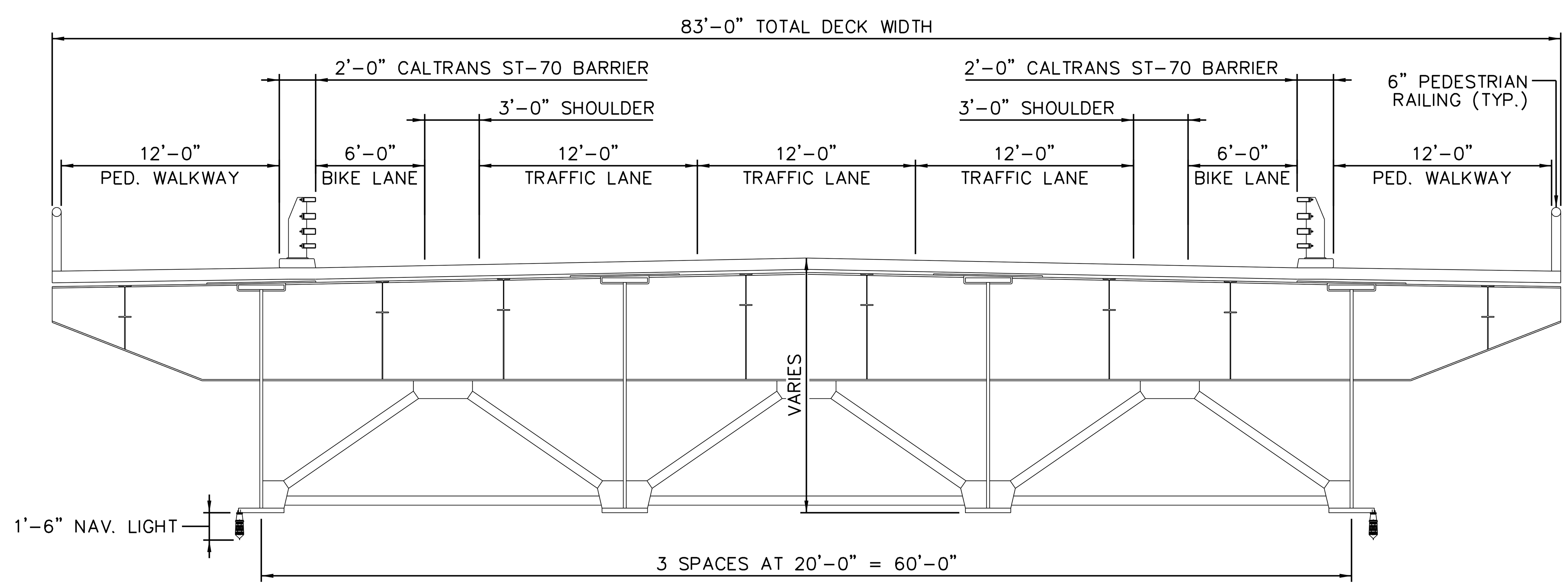
SHEET 19 OF 21

MARCH 2020



ELEVATION

20 0 20 40
SCALE IN FEET



BOBTAIL SWING DECK GIRDER CROSS SECTION

5 0 5 10
SCALE IN FEET

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE I-2
SWING DECK GIRDER SPANS
ELEVATION AND TYPICAL SECTION

MODJESKI and MASTERS
Experience great bridges.

SHEET 20 OF 21

MARCH 2020

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OPERATOR: ALPalmer
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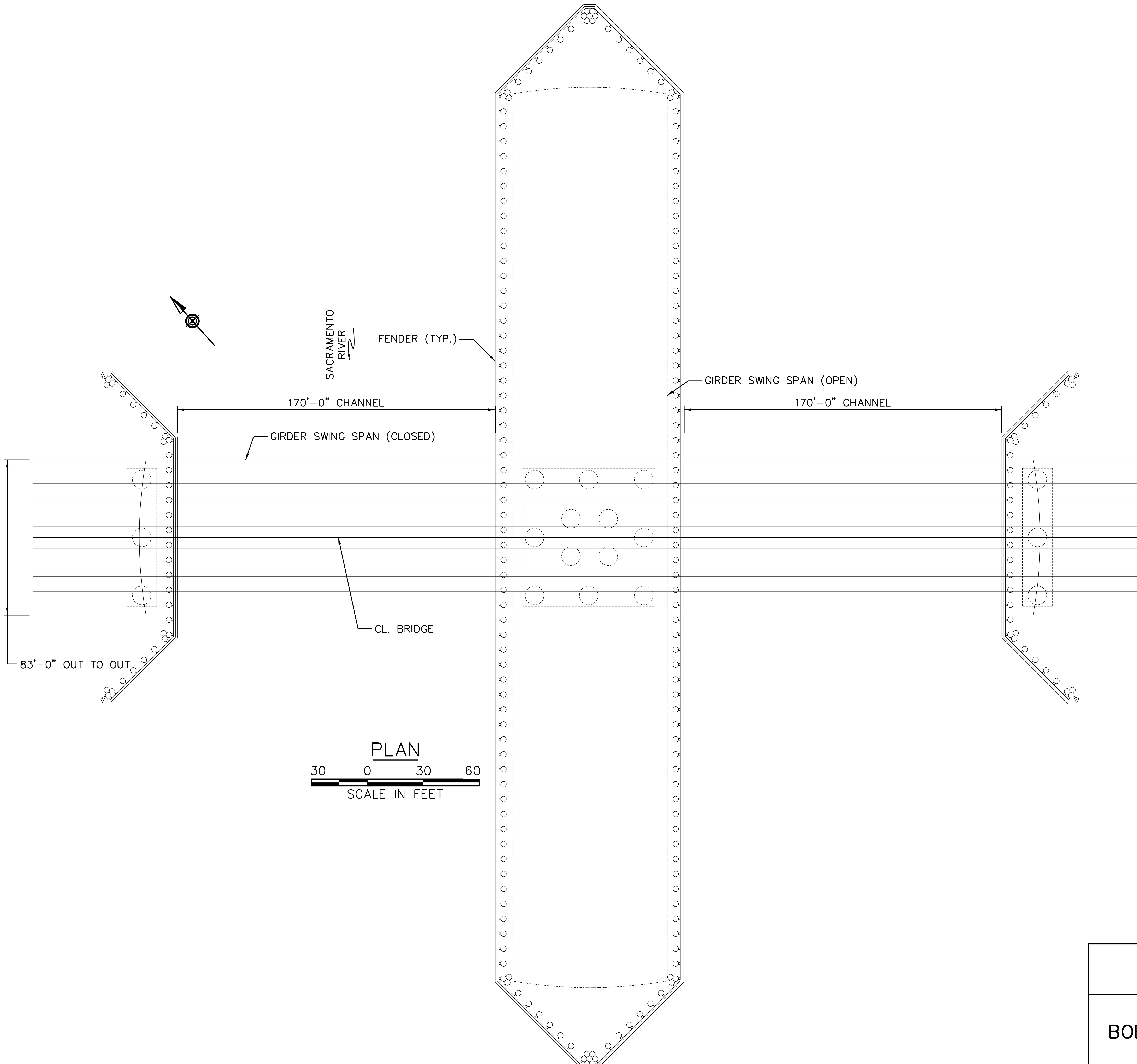

NOTE:
ALTERNATIVE SHOWN ON ALIGNMENT B.

BROADWAY BRIDGE PROJECT

ALTERNATIVE I-2
BOBTAIL SWING DECK GIRDER SPANS
GENERAL PLAN

MODJESKI and MASTERS
Experience great bridges.

SHEET 21 OF 21

MARCH 2020

Appendix B – Evaluation Matrix

MODJESKI and MASTERS

City of West Sacramento
Broadway Bridge Project Approval/Environmental Document Phase
Alignment A&B Broadway Movable Bridge Evaluation Matrix - Case A

Bridge Rating System

1 Poor
2 Fair
3 Good
4 Excellent

			BRIDGE ALTERNATIVES																					
			A		**B**		**C**		**D**		**E**		**F**		**G**		**H-1**		**H-2**		**I-1**		**I-2**	
			Fully Counterweighted Two Leaf Deck Bascule Girder		**Partially Counterweighted Two Leaf Deck Bascule Girder**		**Fully Counterweighted Two Leaf Rolling Bascule Truss**		**Partially Counterweighted Two Leaf Rolling Bascule Truss**		**Vertical Lift Girder Span with Concrete Frame Towers**		**Vertical Lift Girder Span with Steel Frame Towers**		**Vertical Lift Truss Span with Trussed Towers**		**Bobtail Swing Through Truss Spans**		**Swing Through Truss Spans**		**Bobtail Swing Deck Girder Spans**		**Swing Deck Girder Spans**	
Performance	CRITERIA	Weight†	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
	Constructability & Constr. Schedule	40	2	80	2	80	3	120	4	160	3	120	3	120	3	120	3	120	3	120	4	160	4	160
	Environmental and Site Impacts	40	2	80	2	80	4	160	4	160	4	160	4	160	4	160	1	40	1	40	1	40	1	40
	Mobility and Connectivity	10	3	30	4	40	4	40	4	40	4	40	4	40	4	40	3	30	3	30	3	30	3	30
	Future Streetcar	10	3	30	3	30	3	30	3	30	4	40	4	40	4	40	3	30	3	30	3	30	3	30
	Totals	100	10	220	11	230	14	350	15	390	15	360	15	360	15	360	10	220	10	220	11	260	11	260
	Average Weighted Rating		**2.2**		**2.3**		**3.5**		**3.9**		**3.6**		**3.6**		**3.6**		**2.2**		**2.2**		**2.6**		**2.6**	
	Rank		9		8		5		1		2		2		2		9		9		6		6	
	Category Weight / Weighted Rating	50	110		115		175		195		180		180		180		110		110		130		130	
Construction Costs	Construction Cost (Millions)		$94		$90		$93		$91		$88		$83		$87		$88		$94		$88		$94	
	∆ from Low Cost (Millions, %)		$11.1	13%	$7.5	9%	$10.4	13%	$8.4	10%	$4.9	6%	Low Cost	--	$4.1	5%	$5.3	6%	$11.0	13%	$5.0	6%	$10.7	13%
	Rating		**2.4**		**2.9**		**2.5**		**2.8**		**3.3**		**4.0**		**3.4**		**3.3**		**2.5**		**3.3**		**2.5**	
	Rank		11		6		8		7		3		1		2		3		8		3		8	
	Category Weight / Weighted Rating	25	60		72.5		62.5		70		82.5		100		85		82.5		62.5		82.5		62.5	
Life Cycle Costs	CRITERIA	Weight†	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
	Inspection	33	4	132	4	132	3	99	3	99	3	99	2	66	2	66	3	99	2	66	4	132	3	99
	Maintenance	34	3	102	4	136	3	102	4	136	2	68	2	68	2	68	2	68	2	68	2	68	2	68
	Long Term Maint. And Rehab.	33	4	132	4	132	3	99	3	99	3	99	2	66	2	66	3	99	2	66	4	132	3	99
	Totals	100	11	366	12	400	9	300	10	334	8	266	6	200	6	200	8	266	6	200	10	332	8	266
	Average Weighted Rating		**3.7**		**4.0**		**3.0**		**3.3**		**2.7**		**2.0**		**2.0**		**2.7**		**2.0**		**3.3**		**2.7**	
	Rank		2		1		5		3		6		9		9		6		9		4		6	
	Category Weight / Weighted Rating	25	91.5		100		75		83.5		66.5		50		50		66.5		50		83		66.5	
TOTAL WEIGHTED RATING (Highest Possible = 400)			**262**		**288**		**313**		**349**		**329**		**330**		**315**		**259**		**223**		**296**		**259**	
NORMALIZED RATING			**0.75**		**0.82**		**0.90**		**1.00**		**0.94**		**0.95**		**0.90**		**0.74**		**0.64**		**0.85**		**0.74**	
RANK			**8**		**7**		**5**		**1**		**3**		**2**		**4**		**9**		**11**		**6**		**9**	

		RATING SUMMARY OF BRIDGE ALTERNATIVES																					
		A		**B**		**C**		**D**		**E**		**F**		**G**		**H-1**		**H-2**		**I-1**		**I-2**	
		Fully Counterweighted Two Leaf Deck Bascule Girder		**Partially Counterweighted Two Leaf Deck Bascule Girder**		**Fully Counterweighted Two Leaf Rolling Bascule Truss**		**Partially Counterweighted Two Leaf Rolling Bascule Truss**		**Vertical Lift Girder Span with Concrete Frame Towers**		**Vertical Lift Girder Span with Steel Frame Towers**		**Vertical Lift Truss Span with Trussed Towers**		**Bobtail Swing Through Truss Spans**		**Swing Through Truss Spans**		**Bobtail Swing Deck Girder Spans**		**Swing Deck Girder Spans**	
Category	**Weight†**	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank
Performance	50	110	9	115	8	175	5	195	1	180	2	180	2	180	2	110	9	110	9	130	6	130	6
Construction Costs	25	60	11	72.5	6	62.5	8	70	7	82.5	3	100	1	85	2	82.5	3	62.5	8	82.5	3	62.5	8
Life Cycle Costs	25	91.5	2	100	1	75	5	83.5	3	66.5	6	50	9	50	9	66.5	6	50	9	83	4	66.5	6
TOTALS	**100**	**262**	**8**	**288**	**7**	**313**	**5**	**349**	**1**	**329**	**3**	**330**	**2**	**315**	**4**	**259**	**9**	**223**	**11**	**296**	**6**	**259**	**9**
NORMALIZED RATING		**0.75**		**0.82**		**0.90**		**1.00**		**0.94**		**0.95**		**0.90**		**0.74**		**0.64**		**0.85**		**0.74**	

†Weights are assigned a value between 0 and 100 for each criteria. The total weight of each evaluation category should sum to 100.

City of West Sacramento

Broadway Bridge Project Approval/Environmental Document Phase

Alignment C Broadway Movable Bridge Evaluation Matrix - Case A

Bridge Rating System

1 Poor
2 Fair
3 Good
4 Excellent

			BRIDGE ALTERNATIVES																					
			A		**B**		**C**		**D**		**E**		**F**		**G**		**H-1**		**H-2**		**I-1**		**I-2**	
			Fully Counterweighted Two Leaf Deck Bascule Girder		**Partially Counterweighted Two Leaf Deck Bascule Girder**		**Fully Counterweighted Two Leaf Rolling Bascule Truss**		**Partially Counterweighted Two Leaf Rolling Bascule Truss**		**Vertical Lift Girder Span with Concrete Frame Towers**		**Vertical Lift Girder Span with Steel Frame Towers**		**Vertical Lift Truss Span with Trussed Towers**		**Bobtail Swing Through Truss Spans**		**Swing Through Truss Spans**		**Bobtail Swing Deck Girder Spans**		**Swing Deck Girder Spans**	
Performance	CRITERIA	Weight[†]	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
	Constructability & Constr. Schedule	40	2	80	2	80	3	120	4	160	3	120	3	120	3	120	3	120	3	120	4	160	4	160
	Environmental and Site Impacts	40	2	80	2	80	4	160	4	160	4	160	4	160	4	160	1	40	1	40	1	40	1	40
	Mobility and Connectivity	10	3	30	4	40	4	40	4	40	4	40	4	40	4	40	3	30	3	30	3	30	3	30
	Future Streetcar	10	3	30	3	30	3	30	3	30	4	40	4	40	4	40	3	30	3	30	3	30	3	30
	Totals	100	10	220	11	230	14	350	15	390	15	360	15	360	15	360	10	220	10	220	11	260	11	260
	Average Weighted Rating		**2.2**		**2.3**		**3.5**		**3.9**		**3.6**		**3.6**		**3.6**		**2.2**		**2.2**		**2.6**		**2.6**	
	Rank		9		8		5		1		2		2		2		9		9		6		6	
	Category Weight / Weighted Rating	50	110		115		175		195		180		180		180		110		110		130		130	
Construction Costs	Construction Cost (Millions)		$100		$96		$100		$98		$91		$86		$90		$94		$100		$93		$100	
	Δ from Low Cost (Millions, %)		$14.4	17%	$10.5	12%	$14.3	17%	$12.2	14%	$5.2	6%	Low Cost	--	$4.4	5%	$7.9	9%	$14.2	17%	$7.7	9%	$13.9	16%
	Rating		**2.5**		**2.9**		**2.5**		**2.7**		**3.5**		**4.0**		**3.5**		**3.2**		**2.5**		**3.2**		**2.5**	
	Rank		8		6		8		7		2		1		2		4		8		4		8	
	Category Weight / Weighted Rating	25	62.5		72.5		62.5		67.5		87.5		100		87.5		80		62.5		80		62.5	
Life Cycle Costs	CRITERIA	Weight[†]	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
	Inspection	33	4	132	4	132	3	99	3	99	3	99	2	66	2	66	3	99	2	66	4	132	3	99
	Maintenance	34	3	102	4	136	3	102	4	136	2	68	2	68	2	68	2	68	2	68	2	68	2	68
	Long Term Maint. And Rehab.	33	4	132	4	132	3	99	3	99	3	99	2	66	2	66	3	99	2	66	4	132	3	99
	Totals	100	11	366	12	400	9	300	10	334	8	266	6	200	6	200	8	266	6	200	10	332	8	266
	Average Weighted Rating		**3.7**		**4.0**		**3.0**		**3.3**		**2.7**		**2.0**		**2.0**		**2.7**		**2.0**		**3.3**		**2.7**	
	Rank		2		1		5		3		6		9		9		6		9		4		6	
	Category Weight / Weighted Rating	25	91.5		100		75		83.5		66.5		50		50		66.5		50		83		66.5	
TOTAL WEIGHTED RATING (Highest Possible = 400)			**264**		**288**		**313**		**346**		**334**		**330**		**318**		**257**		**223**		**293**		**259**	
NORMALIZED RATING			**0.76**		**0.83**		**0.90**		**1.00**		**0.97**		**0.95**		**0.92**		**0.74**		**0.64**		**0.85**		**0.75**	
RANK			**8**		**7**		**5**		**1**		**2**		**3**		**4**		**10**		**11**		**6**		**9**	

		RATING SUMMARY OF BRIDGE ALTERNATIVES																					
		A		**B**		**C**		**D**		**E**		**F**		**G**		**H-1**		**H-2**		**I-1**		**I-2**	
		Fully Counterweighted Two Leaf Deck Bascule Girder		**Partially Counterweighted Two Leaf Deck Bascule Girder**		**Fully Counterweighted Two Leaf Rolling Bascule Truss**		**Partially Counterweighted Two Leaf Rolling Bascule Truss**		**Vertical Lift Girder Span with Concrete Frame Towers**		**Vertical Lift Girder Span with Steel Frame Towers**		**Vertical Lift Truss Span with Trussed Towers**		**Bobtail Swing Through Truss Spans**		**Swing Through Truss Spans**		**Bobtail Swing Deck Girder Spans**		**Swing Deck Girder Spans**	
Category	**Weight[†]**	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank
Performance	50	110	9	115	8	175	5	195	1	180	2	180	2	180	2	110	9	110	9	130	6	130	6
Construction Costs	25	62.5	8	72.5	6	62.5	8	67.5	7	87.5	2	100	1	87.5	2	80	4	62.5	8	80	4	62.5	8
Life Cycle Costs	25	91.5	2	100	1	75	5	83.5	3	66.5	6	50	9	50	9	66.5	6	50	9	83	4	66.5	6
TOTALS	**100**	**264**	**8**	**288**	**7**	**313**	**5**	**346**	**1**	**334**	**2**	**330**	**3**	**318**	**4**	**257**	**10**	**223**	**11**	**293**	**6**	**259**	**9**
NORMALIZED RATING		**0.76**		**0.83**		**0.90**		**1.00**		**0.97**		**0.95**		**0.92**		**0.74**		**0.64**		**0.85**		**0.75**	

[†]Weights are assigned a value between 0 and 100 for each criteria. The total weight of each evaluation category should sum to 100.

City of West Sacramento
Broadway Bridge Project Approval/Environmental Document Phase
Alignment D Broadway Movable Bridge Evaluation Matrix - Case A

Bridge Rating System

1 Poor
2 Fair
3 Good
4 Excellent

		BRIDGE ALTERNATIVES																					
		A		**B**		**C**		**D**		**E**		**F**		**G**		**H-1**		**H-2**		**I-1**		**I-2**	
		Fully Counterweighted Two Leaf Deck Bascule Girder		**Partially Counterweighted Two Leaf Deck Bascule Girder**		**Fully Counterweighted Two Leaf Rolling Bascule Truss**		**Partially Counterweighted Two Leaf Rolling Bascule Truss**		**Vertical Lift Girder Span with Concrete Frame Towers**		**Vertical Lift Girder Span with Steel Frame Towers**		**Vertical Lift Truss Span with Trussed Towers**		**Bobtail Swing Through Truss Spans**		**Swing Through Truss Spans**		**Bobtail Swing Deck Girder Spans**		**Swing Deck Girder Spans**	
Performance																							
CRITERIA	Weight†	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Constructability & Constr. Schedule	40					3	120	4	160	3	120	3	120	3	120	3	120	3	120				
Environmental and Site Impacts	40					4	160	4	160	4	160	4	160	4	160	1	40	1	40				
Mobility and Connectivity	10					4	40	4	40	4	40	4	40	4	40	3	30	3	30				
Future Streetcar	10					3	30	3	30	4	40	4	40	4	40	3	30	3	30				
Totals	100					14	350	15	390	15	360	15	360	15	360	10	220	10	220				
Average Weighted Rating						**3.5**		**3.9**		**3.6**		**3.6**		**3.6**		**2.2**		**2.2**					
Rank						5		1		2		2		2		6		6					
Category Weight / Weighted Rating	50					175		195		180		180		180		110		110					
Construction Costs																							
Construction Cost (Millions)						$132		$129		$110		$103		$109		$131		$141					
Δ from Low Cost (Millions, %)						$28.6	28%	$25.6	25%	$6.6	6%	Low Cost	--	$5.6	5%	$27.9	27%	$37.5	36%				
Rating						**2.5**		**2.6**		**3.6**		**4.0**		**3.7**		**2.5**		**2.0**					
Rank						5		4		3		1		2		5		7					
Category Weight / Weighted Rating	25					62.5		65		90		100		92.5		62.5		50					
Life Cycle Costs																							
CRITERIA	Weight†	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Inspection	33					3	99	3	99	3	99	2	66	2	66	3	99	2	66				
Maintenance	34					3	102	4	136	2	68	2	68	2	68	2	68	2	68				
Long Term Maint. And Rehab.	33					3	99	3	99	3	99	2	66	2	66	3	99	2	66				
Totals	100					9	300	10	334	8	266	6	200	6	200	8	266	6	200				
Average Weighted Rating						**3.0**		**3.3**		**2.7**		**2.0**		**2.0**		**2.7**		**2.0**					
Rank						2		1		3		5		5		3		5					
Category Weight / Weighted Rating	25					75		83.5		66.5		50		50		66.5		50					
TOTAL WEIGHTED RATING (Highest Possible = 400)						**313**		**344**		**337**		**330**		**323**		**239**		**210**					
NORMALIZED RATING						**0.91**		**1.00**		**0.98**		**0.96**		**0.94**		**0.70**		**0.61**					
RANK						**5**		**1**		**2**		**3**		**4**		**6**		**7**					

		RATING SUMMARY OF BRIDGE ALTERNATIVES																					
		A		**B**		**C**		**D**		**E**		**F**		**G**		**H-1**		**H-2**		**I-1**		**I-2**	
		Fully Counterweighted Two Leaf Deck Bascule Girder		**Partially Counterweighted Two Leaf Deck Bascule Girder**		**Fully Counterweighted Two Leaf Rolling Bascule Truss**		**Partially Counterweighted Two Leaf Rolling Bascule Truss**		**Vertical Lift Girder Span with Concrete Frame Towers**		**Vertical Lift Girder Span with Steel Frame Towers**		**Vertical Lift Truss Span with Trussed Towers**		**Bobtail Swing Through Truss Spans**		**Swing Through Truss Spans**		**Bobtail Swing Deck Girder Spans**		**Swing Deck Girder Spans**	
Category	**Weight†**	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank	Weighted Rating	Rank
Performance	50	0	0	0	0	175	5	195	1	180	2	180	2	180	2	110	6	110	6	0	0	0	0
Construction Costs	25	0	0	0	0	62.5	5	65	4	90	3	100	1	92.5	2	62.5	5	50	7	0	0	0	0
Life Cycle Costs	25	0	0	0	0	75	2	83.5	1	66.5	3	50	5	50	5	66.5	3	50	5	0	0	0	0
TOTALS	**100**	**0**	**0**	**0**	**0**	**313**	**5**	**344**	**1**	**337**	**2**	**330**	**3**	**323**	**4**	**239**	**6**	**210**	**7**	**0**	**0**	**0**	**0**
NORMALIZED RATING		**0.00**		**0.00**		**0.91**		**1.00**		**0.98**		**0.96**		**0.94**		**0.70**		**0.61**		**0.00**		**0.00**	

†Weights are assigned a value between 0 and 100 for each criteria. The total weight of each evaluation category should sum to 100.